CORPS OF ENGINEERS
U.S. ARMY

FROST INVESTIGATIONS
1949 - 1950

INTERIM REPORT
OF
COLD ROOM STUDIES

PREPARED BY
FROST EFFECTS LABORATORY
CORPS OF ENGINEERS, U. S. ARMY
NEW ENGLAND DIVISION, BOSTON, MASS.
FOR
OFFICE OF THE CHIEF OF ENGINEERS
AIRFIELDS BRANCH
ENGINEERING DIVISION
MILITARY CONSTRUCTION

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TABLE OF CONTENTS

TABLE OF CONTENTS (CONT'D)

LIST OF TABLES

LIST OF PLATES

SYNOPSIS

Cold room studies of frost action in soils are being performed by the Frost Effects Laboratory, Corps of Engineers, New England Division for the Airfields Branch, Office, Chief of Engineers, as part of a continuing program of frost investigations aimed toward establishing and improving design and evaluation criteria for roads, highways and airfield runways constructed on soils which are subject to seasonal freezing and thawing. The present laboratory studies are being made chiefly to determine the quantitative effects of individual factors which influence ice segregation in soils, such as gradation, per cent finer than 0.02 mm., per cent rock content, permeability, capillarity, proximity of water supply, density, and the initial degree of saturation in a closed system.

Data from studies completed up to 15 June 1950 are presented in this interim report. Although full analysis has not been attempted pending availability of data and effects of all factors, the data indicated that the per cent finer than 0.02 mm. size is not by itself an adequate indicator and that other factors must be considered, in recognizing a frost susceptible soil or in predicting the intensity of ice segregation in a given soil.

PART I - INTRODUCTION

1-01. Authorization. Laboratory studies of front action in soils were authorized and funds allocated by teletype dated 22 November 1949, File ENGMG 2327, from the Chief of Engineers, Department of the Army. Instructions for the investigation were given in Part III of Instructions and Outline for Frost Investigations - Cold Room Studies (Fiscal Year 1950) dated September 1949 and Addendum No. 1 thereto, dated February 1950.

1-02. Background and Purpose. The increase in the weights of military and commercial aircraft during the last decade has intensified problems encountered in the design of runway pavements, particularly in the northern latitudes where seasonal freezing and thawing of the ground takes place. The formation of ice lenses in frost susceptible soils may result in non-uniform heaving of the pavements and/or loss of pavement supporting capacity during the frost melting period, and costly maintenance or repair measures may be required. Interruptions to traffic as a result of frost action must be avoided.

To develop pavement design and evaluation criteria for such frost conditions the Frost Effects Laboratory was established in the New England Division, in 1944, by authority of the Chief of Engineers, Department of the Army. Since its inception, the Frost Effects Laboratory has conducted field investigations, including traffic tests, at various airfields in the northern part of the United States to observe and study the effects of frost action. As a result of these studies, extensive field data have been compiled from a

number of sites, covering many naturally varying conditions of soil, temperature, and moisture. These data have been assembled by the Frost Effects Laboratory in two published reports entitled "Report on Frost Investigation, 1944-1945", dated April 1947, and "Addendum No. 1, 1945-1947, to Report on Frost Investigation, 1944-1945", dated October 1949. The field studies have shown a need for comprehensive laboratory investigations, under controlled conditions, to study the effect of each of the several variables on frost action in soils.

To meet this need, the Chief of Engineers in June 1949 authorized the construction of a cold room at the Frost Effects Laboratory*. The room was completed and placed in operation in January 1950. Studies which are being conducted with its specially-designed facilities will give a clearer understanding of frost action in soils, and will result in the development of improved criteria for the design and evaluation of pavements. These criteria will be useful in construction not only of airfield runways, taxiways and aprons, but also of roads and highways.

With the available facilities, base course and subgrade soils whose frost susceptibility is in question may be tested in the cold room prior to construction to determine their behavior under freezing conditions. The more precise determination of degree of frost susceptibility thereby made possible will permit closer and, therefore, more economical design. Borderline soils available in the subgrades or in the proximity of construction sites which, under

*In teletype dated 17 June 1949, file ENGMG 2339.

present criteria, would be rejected or would require expensive treatment may in many cases be proven non-frost-susceptible and satisfactory for use after being subjected to the laboratory tests.

1-03. Overall Program of Cold Room Tests. The cold room and its equipment have been designed to enable studies to be made under controlled conditions of all frost phenomena occurring in soils which are reasonably adaptable to investigation by laboratory methods. The presently planned program includes tests to determine the following:

a. Frost susceptibility or non-frost susceptibility of base and subgrade soils from various airfields in northern United States.

b. Effect of density on ice segregation in frost susceptible soils.

c. Effect of initial degree of saturation on ice segregation in a frost-susceptible soil in a closed system, i.e. a system in which no water is made available to the bottom of the sample.

d. Effect of surcharge or overburden pressure on ice segregation in frost susceptible soils.

e. Effect of particle size distribution on ice segregation in soils.

f. Effect of freezing and thawing on density and strength of soils.

g. Effect of soil properties such as void ratio, permeability and capillarity on ice segregation.

h. Effect of proximity of water table on ice segregation in frost-susceptible soils.

i. Loss in strength as measured by direct shear and triaxial compression tests, and by CBR methods, in frost-susceptible soils.

j. Determination of time required for weakened soils to return to normal strength after thawing.

k. Effect of admixtures in preventing or retarding the formation of ice lenses in frost-susceptible soils.

l. Effect of the chemical nature of the soil minerals and of the dissolved salts in the pore water on frost action.

1-04. Scope of Studies Presented in This Report. Laboratory studies in the cold room were begun in February 1950 and are planned to continue through the fiscal year 1951. This report presents only the data and results available from the 80 soil samples which were tested up to 15 June 1950, covering the following partially completed phases of the general program, on which tests are still in progress:

a. Tests to determine the minimum per cent, by weight, of soil particles smaller than 0.02 mm. necessary, to cause ice segregation in any given soil gradation.

b. Tests to determine the effect of soil density on ice segregation.

c. Tests to determine the effect of amount and size of gravel in various soils on the per cent 0.02 mm. size required to cause ice segregation.

d. Tests on the effect of the initial degree of saturation on ice segregation when tested in a closed system.

1-05. Definitions.

FROST HEAVE. Frost heave is the raising of the pavement surface due to the accumulation of ice lenses. The amount of heave in most soils is approximately equal to the cumulative thickness of ice lenses.

FROST-SUSCEPTIBLE SOIL. Previous information has indicated that most soils containing more than 3 per cent of grains finer by weight than 0.02 mm. are susceptible to frost action. However, it has also been found that some uniform sandy soils may have as high as 10 per cent of grains finer than 0.02 mm. by weight, before becoming frost-susceptible.

FROST ACTION. Frost action is the accumulation of water in the form of ice lenses under natural freezing conditions.

ICE LENSES. Ice lenses are the ice formations in stratified frozen soil occurring in repeated layers essentially parallel to each other and normal to the direction of heat loss.

DEGREE OF SATURATION. The ratio, expressed as a percentage, of the volume of water in a given

soil mass to the total volume of intergranular space. Per cent saturation is synonymous with degree of saturation in this report.

GROUND WATER TABLE. The ground water table is the free water surface nearest to the ground surface.

DENSITY. Density is the unit dry weight in pounds per cubic foot.

CAPILLARITY. Capillarity is that property which enables a soil to draw and hold water above the elevation at which atmospheric pressure exists in the water.

OVERBURDEN PRESSURE. Overburden pressure is the force exerted at any given point in a soil by the weight of the overlying material.

CLOSED SYSTEM. A closed system in this report is defined as a test condition where no free water is made available from outside the specimen during the freezing process.

OPEN SYSTEM. An open system in this report is defined as a test condition where free water is made available from outside the specimen during the freezing process.

PART II - DESCRIPTION OF COLD ROOM AND EQUIPMENT

2-01. Cold Room. The cold room is a walk-in type refrigerator, approximately 9 feet wide by 20 feet long and 6.5 feet high in inside dimensions. It is insulated on all sides with six inches of mineral wool. It is constructed of 22 separate panels which are bolted together, enabling reasonably easy dismantling and providing flexibility for enlargement when and if necessary. The panels are faced on both sides with 20-gauge galvanized sheet metal. A cut-away view of the cold room is shown on Plate 1.

A 1½-H.P. water-cooled compressor located outside the cold room wall furnishes the Freon gas refrigerant to two unit coolers mounted at the rear of the cold room. Temperature is controlled with a Minneapolis-Honeywell bimetallic mercury bulb thermostat, within limits of plus or minus 2 degrees Fahrenheit. The cold room has been designed to operate between plus 10 and plus 40 degrees Fahrenheit.

2-02. Test Cabinets. Nine individual test cabinets insulated on the top and sides with six inches of sheet cork are located in the cold room. Refrigerant is provided separately to each by 1/4-H.P. air-cooled units, shown in Fig. 1 of Plate 2. The test cabinets have been designed to operate at temperatures ranging from the cold room temperature to minus 20 degrees Fahrenheit. Temperature in each cabinet is controlled by a De Khotinsky bimetallic helical type thermoregulator with an accuracy of plus or minus 1/2 degree Fahrenheit. Exterior views of the test cabinets are shown in Fig. 2 of Plate 2 and on Plate 3.

The bottoms of the test cabinets consist of open grill work (Fig. 1, Plate 4) to allow the cold room temperature to be applied to the bottoms of the soil specimens being tested, while the tops of the samples are being subjected to the cabinet temperatures. During freezing tests, cabinet temperatures are gradually lowered in small daily decrements to produce a rate of frost penetration into the samples simulating natural field conditions. Samples are placed over porous discs in individual receptacles to which water can be supplied if necessary. These receptacles rest on a galvanized sheet metal plate placed over the grill work (Fig. 2 of Plate 4). The space between samples is insulated with granulated cork as shown in Fig. 1 of Plate 5. Cooling inside the test cabinet is accomplished by passing the refrigerant through single embossed coils inside a 14-inch wide zinc-coated copper refrigerating plate fitted to three sides of the cabinet, beginning 13 inches from the bottom and continuing to the top.

The cabinets have an inside dimension of 19 inches by 19 inches and can accommodate soil specimens up to 12 inches high. A typical prepared 6-inch high specimen is shown in Fig. 2 of Plate 5. All cabinets are equipped with hinged covers on top, facilitating access to cabinet for observations and necessary measurements with insignificant disturbance to the cabinet temperature. Usually, four specimens either 4.18 or 5.91 inches in diameter are tested simultaneously in one cabinet, although as many as 36 three-inch diameter samples may be tested in each cabinet at one time. A section through

the cabinets is shown on Plate 6.

Facilities for furnishing de-aired water to any specimen and for maintaining a definite water level within the specimens in a test cabinet are provided by constant water level devices which are adjustable over the range of the height of the sample. These are shown in Fig. 1 and Fig. 2 of Plate 3. The water level devices are supplied with water from a 6-gallon tank located in the cold room as shown in Fig. 1 of Plate 8. The water supply to this tank is controlled with a copper float valve.

2-03. Saturating Equipment. Facilities for saturating soil specimens to be tested are located in the cold room. Six specimens can be saturated at one time. Prior to saturation, soil specimens in cylindrical cardboard containers are fitted on both ends with filter paper, porous discs 3/8-inches thick, and the brass caps which also serve as sample receptacles in the freezing cabinets. The caps are firmly sealed to the cardboard with rubber sleeves and bands to prevent air leakage. The vacuum lines were connected to the threaded nipples on both top and bottom caps and the specimens were evacuated. De-aired water was then allowed to enter the specimen from the bottom, slowly, under a small head until saturated. Control is provided by means of suitable valves. A photograph showing samples undergoing saturation is shown in Fig. 1 of Plate 7.

2-04. Surcharge Loads. For application of surcharge loads a circular 1/4-inch steel base plate, 6 inches in diameter is used, to which are welded four lugs which support the rectangular lead weights;

the lead weights are raised approximately 1-1/2 inches from the base plate to allow cold cabinet air to circulate over the base plate. Evaporation of soil moisture is prevented by the steel plate.

2-05. Temperature Measuring Equipment. The temperatures in soil specimens are measured by means of copper-constantan thermocouples. The thermal electromotive force produced by the thermocouples is measured by electrical instruments consisting of a standard cell, sensitive galvanometer, and a Leeds & Northrup, type K-2, potentiometer. Temperatures are read and recorded to 0.1 degrees Fahrenheit. A toggle switchboard enables any one of 100 available thermocouples to be placed rapidly in the measuring circuit. This equipment is conveniently placed in an instrument room outside the cold room wall. The equipment is shown in Fig. 2 of Plate 7, and the location of the instrument room is indicated on Plate 1.

Each test box is equipped with a glass thermometer which can be read from the outside through the thermopane window. A close check of each cabinet temperature is maintained, however, by means of a thermocouple inserted in a glycerin-filled, rubber-stoppered, glass vial, 1 inch in diameter and 3 inches long, suspended near the specimens. The glycerin damps out the temperature fluctuations occurring in the test cabinet during a normal operating cycle of the compressor, thus permitting an average temperature to be read and recorded. The value of the average daily cabinet temperature is determined from the average of several readings with the thermocouple in the vial. Typical weekly records of test cabinet and

cold room temperatures recorded with thermographs are shown in Fig. 1 and Fig. 2 of Plate 9.

PART III - TEST PROCEDURES

3-01. Molding of Specimens. The specimens tested in the cold room for this investigation were prepared in steel cylinders in either one of two sizes - either 4.18 inches or 5.91 inches in diameter and all six inches high. Generally, the fine grained soils or those containing grains smaller than 1/4 inch were prepared in the 4.18-inch diameter mold, and soils with stones up to 2 inches in diameter were prepared in the 5.91-inch diameter steel mold. No specimens were tested containing stones larger than 2 inches in size.

Two methods were used in compacting these specimens to the desired density. Coarse grained or gravelly soils such as the sands and gravelly sands, were generally prepared by an adaptation of the Providence Vibrated Density Test method. In the method used, a predetermined dry weight of soil is placed in the steel cylinder and a load of approximately 1000 pounds applied by a piston at each end and a heavy spring at the top. The soil within the cylinder is compacted by vibrating the cylinder with hammer blows on the sides. Fine grained soils such as the uniform fine sands, silts and glacial tills were prepared in an open-ended steel cylinder by applying pressure to movable pistons at both ends with a Southwark-Emery compression machine, using an average pressure of 1500 pounds per square inch and a maximum of 4,000 pounds per square inch. Some specimens were prepared by a combination of the two methods described.

During the early stages of the testing program, split molding cylinders were used but were later replaced by solid steel cylinders because of distortion caused by hammer blows. Samples were removed from the latter cylinders by piston pressure at the bottom of the sample, the inside walls of the cylinder having been lubricated with a thin coating of petrolatum followed by paraffin before molding. The split molding cylinders, of both diameters, are shown in Fig. 2 of Plate 8.

Specimens were compacted at optimum water content to densities approximately 95 per cent of Modified A.A.S.H.O. density or of Providence Vibrated density, whichever was applicable for the type of soil being tested. Base and subgrade soils obtained from beneath airfield pavements were compacted to approximately natural field densities as shown in Airfield Pavement Evaluation Reports.

After removal from the molding cylinders the sides of the cylindrical specimen, excluding top and bottom faces, were sprayed with a light coating of a plastic material to hold the sample together during handling and to prevent evaporation. Over the plastic coating a heavy layer of petrolatum was applied and the specimens were fitted snugly into 6-inch high cardboard cylinders open on both ends.

3-02. Saturation of Specimens. All specimens tested in the open system were saturated prior to freezing. Saturation was carried out in the cold room with equipment described in paragraph 2-03 and shown in Fig. 1 of Plate 7. The degree of saturation for

each specimen was computed from weights of sample and container before and after saturating.

3-03. Placing Specimens in Test Cabinet. After saturation, the specimens were placed in the test cabinet, the upper cap or receptacle removed and the bottom receptacle kept in place. Four samples were placed in each cabinet. The de-aired water supply was connected to the bottom of each receptacle, the constant water level device having been previously adjusted to a height such that the water in the receptacle would rise to approximately 1/8 inch above the porous stone and be in contact with the soil. The specimens were insulated from each other with granulated cork as shown on Plate 6.

3-04. Surcharge. Each specimen was tested under a surcharge load of 0.5 pounds per square inch to simulate field conditions consisting of a 6-inch thickness of pavement and base. A very thin layer of bentonite was spread over the top of the sample before the base plate was set to provide a uniform contact between the steel surcharge weight base plate and the soil particles.

3-05. Thermocouples in Samples. Thermocouples were placed at 1-inch intervals, along the longitudinal axis including top and bottom, in one of the four specimens in a test cabinet, providing a means of checking the temperatures within the specimen and observing the progress of freezing temperature into the specimen. Two thermocouples were placed in one other specimen in the cabinet, on top and bottom only, for checking purposes. The thermocouples were inserted

through the side of the specimen in holes punched with a slender, pointed instrument. Entrance points were sealed with heavy grease.

3-06. Specimen Freezing Procedure. Tests were begun when the specimens in the cabinet had cooled uniformly to cold room temperature of approximately 38°F., which usually was attained after the specimens were in place overnight with the cabinet lid open. The freezing test was started by closing the lid and lowering the temperature in the cabinet to approximately 30°F. for a period of two days and then dropping it to 29°F. for two more days and to 28°F. for two days. After than period, the temperatures within the cabinet were changed only by an amount necessary to maintain the rate of penetration of the 32°F. temperature in the samples at approximately 1/4 inch per day. Temperatures within the soil specimens were read daily and temperatures in the cabinets were adjusted accordingly, depending upon the progress of the 32°F. temperature within the sample. Readings of vial temperatures (par. 2-05) to determine the average daily cabinet temperature were obtained at intervals of 10 to 15 minutes for a continuous period of 1 to 2 hours each day. A typical plot showing the daily temperature gradients in a sample of undisturbed Boston Blue Clay is shown on Plate 20. The position of the 32°F. temperature in the sample is indicated by the intersection of the temperature gradient and the 32°F. line.

Heave readings were made daily and were read to the nearest half-millimeter. Measurements were obtained with a meter

stick placed on a designated point on the surcharge weights over the sample; the reading was taken at the intersection of the stick and a steel bar across the top of the cabinet opening.

Plots have been prepared for each group of specimens tested in an individual cabinet showing the heave, degree-hours and penetration of the 32°F. vs. time. These are presented on Plates 22 to 41 inclusive, in the order presented in Table 1.

At completion of test, usually after 24 days, the samples were removed from their containers, weighed to determine the change in water content, and then split in two, longitudinally, in a compression machine with the aid of a steel wedge. A photograph of a sample being split is shown on Plate 21. Measurements for amount of heave and observations for the location, distribution and magnitude of ice lens formation were made on one-half of the specimen. The remaining half of the sample was photographed and retained for supplemental laboratory tests. Photographs of typical specimens after splitting are shown on Plates 42 to 49 inclusive. Water contents were obtained at every inch of the split specimen. Water content distribution for each specimen tested, before and after freezing is shown on Plates 50 to 69 inclusive.

3-07. <u>Supplementary Laboratory Tests</u>. The following laboratory tests were performed on all specimens tested, for correlation if possible with heave or rate of ice segregation:

a. Gradation

b. Permeability

c. Specific gravity

d. Atterberg Limits (if applicable)

e. Compaction characteristics (if necessary)

Standard procedures were used, which are not considered necessary to describe in detail at the present preliminary stage of the investigations.

PART IV - TESTS IN FISCAL YEAR 1950

4-01. Soils Selected for Tests. The soils selected for testing in this investigation are summarized in Table A on the following page. As shown thereon they consist of two main groups: (a) seven basic soils ranging from a well-graded sandy gravel (GW) to a medium plastic clay (CL), chosen for testing both in their natural conditions and in various blends with one another in order to vary the physical characteristics which influence ice segregation and (b) base and subgrade soils obtained from 13 airfields in northern United States and one from Alaska, to be tested for degree of frost susceptibility for correlation with data available in the Frost Investigation Reports and/or Pavement Failure Reports.

4-02. Status of Investigations. The studies initiated up to 15 June 1950 have been summarized in paragraph 1-04 and are outlined in greater detail in Table B, where the specific materials tested are listed. The cold room test results available on 15 June 1950 have been summarized in Table 1, at the end of the report which also presents the results of such other basic tests on permeability, specific gravity and Atterberg Limits. Table 2 presents the initial degree of saturation of each specimen at the start of the tests.

Detailed analysis of the results to date is not attempted at this time. Because of the interrelationship of the numerous factors to be examined, such analysis should await completion of the program, so that effects of all factors may be considered together.

TABLE A
SOILS SELECTED FOR COLD ROOM TEST PROGRAM

TEST IDENTIFICATION SYMBOL	SOURCE	DESCRIPTION	CORPS OF ENGINEERS UNIFORM SOIL CLASSIFICATION	% FINER THAN #200 MESH SIEVE	% FINER THAN 0.02 mm.	GRADATION SHOWN ON PLATE NO.	MAXIMUM DRY DENSITY
(a) BASIC SOILS							
LSG	Limestone AFB, Limestone, Maine	Typical sandy gravel Base material	GW	7	5	10	139 (2)
AG	Peabody, Massachusetts	Clean sandy gravel (Used to make artificial gradations for blending with other soils. Denoted by symbols AG1 and AG2	GW	< 1		10	130 (3)
LS	Lowell, Massachusetts	Well-graded sand (1)	SW	3		10	110 (3)
MFS	Manchester, New Hampshire	Uniform fine sand (1)	SP	8	1	10	109 (3)
NH	Goff's Falls, New Hampshire (Referred to as New Hampshire Silt)	Silt	ML	97	58	10	107 (4)
EBT	Governor's Island, East Boston (Referred to as East Boston Till)	Gravelly, sandy silt (Glacial Till)	ML	57	44	10	131 (4)
BC	North Cambridge, Massachusetts (Referred to as Boston Blue Clay)	Clay	CL	99	84	10	
(b) TYPICAL BASES AND SUBGRADES FROM VARIOUS AIRFIELDS							
TI	Truax AFB, Madison, Wisconsin	Base or subbase (Tested in natural and artificial gradations)	SM	16-18	28-30	11	
LA	Lowry AFB, Denver, Colorado	Silty sand Subgrade	SM	36-42	24-31	12	
PA	Pierre Airfield, Pierre, South Dakota	Silty gravelly sand Base	SM	17	9	13	
CA	Casper AFB, Casper, Wyoming	Silty gravelly sand Base Silty sand Subgrade	SM SM	23 21-29	15 16-18	13	
FA	Fargo Municipal Airfield, Fargo, N.D.	Clayey sand Base	SC	16	9	14	
WN	Wendover AFB, Wendover, Utah	Silty sandy gravel Base	GM	14	9	14	
SF	Sioux Falls Airfield Sioux Falls, S.D.	Silty sandy gravel Base	GM	15	9	14	
RC	Rapid City AFB (Weaver Airbase) Rapid City, S.D.	Silty sandy gravel Base	GM	12	8	14	
LF	Ladd Field, Fairbanks, Alaska	Silt Subsoil	ML	91	57	14	
HF	Hill AFB, Ogden, Utah	Silty sand Subgrade	SM	27	13	15	
PT	Patterson Field, Fairfield, Ohio	Clayey sandy gravel Base	GC	22	15	15	
CL	Clinton County AFB, Wilmington, Ohio	Clayey sandy gravel-Base	GC	20	14	15	
SPF	Spokane AFB, Spokane, Washington	Gravelly sand Base	SP	6	4	15	

NOTES: (1) Blended with New Hampshire Silt and also with East Boston Till to vary the fines.
(2) Providence Vibrated Density on minus 1/4-inch material.
(3) Providence Vibrated Density on minus 1/2-inch material.
(4) Modified AASHO Method.

TABLE B
SUMMARY OF TESTS CONDUCTED TO 15 JUNE 1950

STUDY*	MATERIALS TESTED	SAMPLE NOS.	GRADATION SHOWN ON PLATE NO.	STATUS OF TESTS ON 15 JUNE 1950
Effect of Percent < 0.02 mm.	(1) Limestone sandy gravel, 3/4-inch maximum size.	LSG-1 thru LSG-4	16 (Sheet 1 of 3)	Incomplete
	(2) Peabody sandy gravel blended with New Hampshire Silt, 1/2-inch maximum size.	AG1-1 thru AG1-8	17 (Sheets 1 and 2 of 3)	
	(3) Peabody sandy gravel blended with East Boston Till, 1/4-inch maximum size.	AG2-5 thru AG2-8	17 (Sheet 3 of 3)	
	(4) Lowell sand blended with East Boston Till.	LS-1 thru LS-4	18	
	(5) Manchester Fine Sand blended with East Boston Till.	MFS-1 thru MFS-4	19 (Sheet 1 of 3)	
	(6) Manchester Fine Sand blended with New Hampshire Silt.	MFS-5 thru MFS-12	19 (Sheets 2 and 3 of 3)	
	(7) Truax base or subbase material (TD-1 thru TD-4 were regraded to vary the fines; TD-5 is a mixture of two typical subgrade samples; TD-6 is a natural typical subgrade soil).	TD-1 thru TD-6	11	
Effect of Density	(1) New Hampshire Silt.	NH-1 thru NH-4	10	Incomplete
	(2) East Boston Till, 3/4-inch maximum size.	EBT-1 thru EBT-4	10	
	(3) Ladd Field, Alaska, Silt subsoil.	LF-1 thru LF-4	14	
	(4) Limestone sandy gravel, 3/4-inch maximum size. (Graded to contain 3% finer than 0.02 mm.)	LSG-5 thru LSG-8	16 (Sheet 1 of 3)	
Effect of Stone Size	(1) Limestone sandy gravel specially graded with 3% finer than 0.02 mm. with max. stone sizes varying from 1/4 to 2-inches.	LSG-9 thru LSG-12	16 (Sheet 2 of 3)	Incomplete
	(2) Limestone sandy gravel, natural gradation. Samples "scalped" at 2, 1, 1/2 and 1/4-inches respectively, thus, increasing the percent fines.	LSG-13 thru LSG-16	16 (Sheet 2 of 3)	
Ice Segregation in Saturated Clay in a Closed System	(1) Undisturbed Boston Blue Clay. 100% saturated.	BC-1, BC-2, BC-5, BC-6	10	Incomplete

*All tests, except the four completed on Boston Blue Clay to examine ice segregation in a closed system, were performed with an open system, that is, with free water available at the base of the specimen.

4-03. Tests for Effect of Per Cent Finer Than 0.02 mm. As shown in plot of per cent heave vs. per cent finer than 0.02 mm. on Plate 70, the present criterion, stating that well-graded soils with three per cent or less, by weight, of grains finer than 0.02 mm. are not frost susceptible is only a rough approximation and does not always hold. This is shown by specimens of sand and gravel base material from Limestone Air Force Base, Limestone, Maine, Samples LSG-5 to LSG-8, inclusive, which heaved from 8 to 19 per cent with only 3 per cent, by weight, finer than 0.02 mm. A base course material from Spokane AFB, Spokane, Washington, heaved 13.6 per cent with only 4 per cent finer than 0.02 mm. It would appear that a criterion based on a percentage at some arbitrary grain size is subject to the same variability as is encountered in attempts to predict permeability from soil gradation characteristics.

4-04. Tests for Effect of Density. Density serves as an overall measure of the combined effects of such soil characteristics as permeability, capillarity and internal structure, in a given material.

The data thus far available on the effect of density on ice segregation are plotted on Plate 71. The data on this plate indicate that heaving increases with density in silt soils such as New Hampshire Silt and Ladd Field, Alaska, subsoil. Tests on East Boston Till showed increased heaving with an increase in density up to 120 lbs. per cu.ft. and then a rapid decrease in heaving with further increase in density. Tests on the sandy gravel from Limestone, Maine indicated no appreciable change of heaving with density.

4-05. Tests for Effect of Permeability. Permeability (together with capillarity) should of course, offer the most direct measure of the susceptibility of an ordinary soil to frost action.

The coefficients of permeability versus the per cent heave for most of the soils tested are plotted on Plate 72. The data indicate that a critical value of the coefficient of permeability exists at which frost heaving is a maximum, and that heaving decreases in soils having coefficients of permeability either higher or lower than this critical value. No tests have been conducted to date to determine the lower limit which probably exists in highly impervious clays and in which ice segregation may be impossible. Permeability tests were conducted on soils with the same gradation as tested in the cold room and shown on Plates 10 to 19, inclusive.

4-06. Tests for Effect of Size and Per Cent Stone. Data from tests on four specimens of sandy gravel from Limestone, Maine, samples LSG-9 to LSG-12, inclusive, show decrease in heave with increase in the maximum size stone from 1/4-inch to 2-inches in diameter, the percentage finer than 2.0 mm. and 0.02 mm. being held the same in each case (30 and 3 per cent, respectively). The data obtained from testing four specimens of pit-run sandy gravel from Limestone, Maine, wherein the maximum stone sizes were decreased (scalped) each time allowing the percentage of fines to increase, were inconsistent and no analysis can be made until further tests are conducted.

4-07. Tests on Saturated Clay in Closed System. Four samples of undisturbed Boston Blue Clay, 100 per cent saturated, tested in a

closed system, heaved from 8 to 14 per cent, thus indicating that considerable heaving can be expected in certain types of soils without availability of outside water.

4-08. Penetration of 32°F. Temperature. In plotting the penetration of the 32°F. temperature (the assumed freezing temperature of soil moisture) versus depth, a peculiarity common to all specimens tested was observed. As shown on Plate 22 to 41, inclusive, the 32°F. temperature, after progressing into the sample for a distance of 2 to 4 inches suddenly recedes, generally from 1 to 2 inches, before proceeding downward again. At first this drop-back in temperature was believed to be the result of either instrumentation or fluctuation of temperature within the cold room or freezing cabinets. Reoccurrence of the phenomena and close check of temperature measuring equipment indicate that the temperature recession is not the result of faulty equipment or temperature control, but is the result of changes occurring within the soil specimen during the freezing process. It is believed that this phenomenon is due to the release of latent heat of fusion when the soil moisture begins to freeze at the top of the sample at some temperature less than 32°F. It was also observed that heaving commenced only after the temperature recession had occurred. Investigations are being conducted to determine the exact cause of this phenomena.

4-09. Maximum Rate of Heave and Penetration of Freezing Temperature. The maximum rate of heave of each specimen tested is shown on Plate 1, in the column third from the end. The range of

rate of freezing temperature penetration (assumed 32°F.) at the maximum rate of heave is presented in the second column from the end in Table 1. These values were obtained from data plotted on Plates 22 to 41, inclusive.

4-10. Temperature at Boundary of Frozen and Unfrozen Soil. In the last column of Table 1 are presented the temperatures at the boundary of frozen and unfrozen soil, in the specimens containing thermocouples. These temperatures were obtained by interpolation between thermocouple readings taken immediately prior to removal of the samples from the cabinets at the completion of the tests. These temperatures are only approximate since the positions of the thermocouples at time of observation were not known precisely, the thermocouples having been displaced in some instances by the heaving of the soil. The interpolations were made on the basis of the thermocouples being in their original approximate positions. The temperature data indicate that soil moisture, in the soils tested, freezes at temperatures ranging from 29.1°F. to 32°F., with the lower values in silty and clayey soils.

PART V - CONCLUSIONS

5-01. General. The preliminary conclusions presented below are based on the partially completed phases of the cold room studies and on data available up to 15 June 1950. They are general only insofar as they apply to the materials tested and are subject to modification or change pending the final completion of each phase of the investigation. Except for the few results derived from closed system tests, all conclusions are drawn from the case of a soil with free access to water.

a. Effect of Per Cent Finer than 0.02 mm. on Ice Segregation. The test results available to date indicate that factors other than 0.02 mm. size must be considered in recognizing a frost susceptible soil or in predicting the intensity of ice segregation in any given soil. Since it is believed that soils heaving five percent or more will experience softening upon thawing, and since heaves several times this percentage resulted in some soils having approximately 3% finer than 0.02 mm., revisions to the existing criteria may be necessary when additional information becomes available.

b. Effect of Density on Ice Segregation. Ice segregation may either increase or decrease with increase in density, and the effect of density change may be marked or negligible depending on the density range investigated and the characteristics of the particular soil.

c. Effect of Permeability. The test results indicate that intensity of ice segregation increases in soils with a decrease in the coefficient of permeability below a value of about $k = 10 \times 10^{-4}$

cm/sec. and maximum heaves result between permeabilities of about 0.001 and 0.05 x 10^{-4} cm/sec. Based on the results of one test series the intensity of ice segregation diminishes with reduction in coefficient of permeability below about 0.005 x 10^{-4} cm/sec., although the per cent heave may nevertheless be relatively high.

d. Effect of Size and Per Cent Stone. Increasing the maximum size stone from 1/4 to 2 inches in diameter decreased the amount of heave in a gradation of Limestone sandy gravel in which the gradation of the material finer than 2.0 mm. was held constant.

e. Ice Segregation in Saturated Clay in A Closed System. Considerable ice segregation can be expected to occur by slowly freezing a fully saturated clay soil in a closed system.

f. Maximum Rate of Heave and Penetration of Freezing Temperature. No relationship appears to exist between the maximum rate of heave and the rate of freezing temperature penetration within the range of rates of these tests.

g. Temperature at Boundary of Frozen and Unfrozen Soil For the soils tested the freezing temperature of soil moisture in the coarse grained soils is 32°F. or slightly less and generally decreases to approximately 29°F. with increasing percentages of silt and clay sizes.

5-02. Equipment and Test Procedures. It is concluded that the equipment and test procedures devised are satisfactory for simulating field conditions and frost action in soils, and that the

results may be utilized to establish or modify design criteria. Full evaluation of the testing system must await completion of tests on the base and subbase materials of known frost characteristics, from the various airfields.

PART VI - RECOMMENDATIONS

6-01. Recommendations. It is recommended that Cold Room Studies directed towards establishing and improving design and evaluation criteria for the construction of airfield pavements on frost susceptible soils be continued to complete the studies initiated in Fiscal Year 1950 and to study the effect of the following additional factors influencing ice segregation in soils:

a. Effect of alternate freezing and thawing on density of frost susceptible soils.

b. Effect of depth of water table and its influence on ice segregation in frost susceptible soils.

c. Effect of initial degree of saturation in a closed system.

d. Intensity of pore pressure in soils during freezing.

e. Effect of chemical constituents of soils on ice segregation.

f. Effect of soil capillarity on ice segregation.

g. Strength of frost susceptible soils upon thawing.

h. Treatment of frost susceptible bases and subgrades with admixtures to retard or prevent ice segregation.

i. The freezing point of soil moisture in various types of soils.

[illegible] NUMBER	SOIL	PERCENT < 0.02 mm. BY WEIGHT	COMBINED SPECIFIC GRAVITY	ORIGINAL HEIGHT (Inches)	[illegible] OF [illegible] (Inches)	[illegible] Inches	[illegible] HEAVE (1)	[illegible]
LSG-1	Limestone AFB Sand and Gravel (3/4" max. size)	3	2.71	6.[illegible]	-	0.1[illegible]	2.1	[illegible]
LSG-2		[illegible]	2.71	6.00	-	[illegible]	[illegible]	[illegible]
LSG-3		6	2.71	6.00	-	1.[illegible]	15.1	[illegible]
LSG-4		9	2.71	[illegible]	-	[illegible]	14.7	[illegible]
LSG-5	Limestone AFB Sand and Gravel (3/4" max. size)	3	2.71	6.10	0.60	[illegible]	15.[illegible]	[illegible]
LSG-6		3	2.71	6.00	-	[illegible]	[illegible]	[illegible]
LSG-7		[illegible]	2.71	[illegible]	-	1.[illegible]	1[illegible]	[illegible]
LSG-8		3	2.71	[illegible]	-	1.[illegible]	1[illegible]	[illegible]
LSG-9	Limestone AFB Sand and Gravel (Max. sizes as shown) 2"	3	2.71	[illegible]	0.[illegible]	0.56	10.[illegible]	[illegible]
LSG-10	1"	[illegible]	2.72	[illegible]	-	[illegible]	[illegible]	[illegible]
LSG-11	1/2"	[illegible]	2.71	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
LSG-12	1/4"	3	2.71	[illegible]	-	1.3[illegible]	22.[illegible]	[illegible]
LSG-13	Limestone AFB Sand and Gravel (Max. sizes as shown) 2"	[illegible]	2.72	[illegible]	[illegible]	1.[illegible]	[illegible]	[illegible]
LSG-14	1"	[illegible]	2.71	[illegible]	[illegible]	1.[illegible]	[illegible]	[illegible]
LSG-15	1/2"	10	[illegible]	[illegible]	[illegible]	1.[illegible]	[illegible]	[illegible]
LSG-16	1/4"	13	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MFS-1	Manchester Fine Sand blended with East Boston Till.	[illegible]	2.6[illegible]	[illegible]	-	[illegible]	[illegible]	[illegible]
MFS-2		[illegible]	2.6[illegible]	[illegible]	-	[illegible]	1[illegible]	[illegible]
MFS-3		[illegible]	[illegible]	[illegible]	-	[illegible]	1[illegible]	[illegible]
MFS-4		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MFS-5	Manchester Fine Sand blended with New Hampshire Silt	7	2.6[illegible]	[illegible]	0.[illegible]	[illegible]	[illegible]	[illegible]
MFS-6		[illegible]	2.6[illegible]	[illegible]	-	[illegible]	[illegible]	[illegible]
MFS-7		[illegible]	[illegible]	[illegible]	-	[illegible]	[illegible]	[illegible]
MFS-8		[illegible]	2.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MFS-9	Manchester Fine Sand blended with New Hampshire Silt	[illegible]	[illegible]	[illegible]	[illegible]	0.37	[illegible]	[illegible]
MFS-10		18	2.65	[illegible]	0.[illegible]	[illegible]	[illegible]	[illegible]
MSF-11		21	[illegible]	[illegible]	0.[illegible]	[illegible]	[illegible]	[illegible]
MSF-12		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

(1) Based on height of frozen portion, before freezing.

(2) Water [illegible] for a 10 [illegible] or is the [illegible] less.

SUMMARY OF TEST DATA

[illegible]	DRY DENSITY lbs./ft³	WATER CONTENT % DRY WEIGHT: BEFORE FREEZING (2)	WATER CONTENT % DRY WEIGHT: GAIN OR LOSS DURING FREEZING	PERCENT STONES >2.0 mm.	VOID RATIO e	PERMEABILITY K x 10⁻⁴ (cm/sec.)	ATTERBERG LIMITS Minus #40 Sieve: L.L.	P.L.	P.I.	MAXIMUM RATE OF HEAVE cm./day	RANGE OF R[illegible] FROST PEN[illegible] MAX. RA[illegible] OF HEAV[illegible] (Inches [illegible])
1	135.4	8.0	+ 7.[illegible]	6[illegible]	0.2[illegible]0	1.9	Test	in Progress		0.15	.10-.[illegible]
[illegible]	1[illegible].4	8.[illegible]	+ [illegible]	6[illegible]	0.2[illegible]0	[illegible]		"		0.25	
1	135.[illegible]	8.6	+ [illegible]	69	0.240	0.2		"		0.[illegible]	
7	1[illegible]6.4	[illegible].9	+ [illegible]	6[illegible]	0.21[illegible]	0.[illegible]7	25.[illegible]	1[illegible].[illegible]	7.0	0.[illegible]	
[illegible]	1[illegible]5.9	12.5	+ 1.[illegible]	67	0.370	Test	in Progress			0.20	.1[illegible]
[illegible]	1[illegible]0.0	10.8	+ [illegible].3	67	0.300					0.15	
	1[illegible]6.7	5.6	+ [illegible].2	67	0.23[illegible]	"				0.[illegible]	
	1[illegible]6.7	[illegible]	+ [illegible]	67	0.235	"				.[illegible]	
	1[illegible].7	[illegible]	+ 0.1	7[illegible]	0.250	Test	in Progress			0.20	-.20-.[illegible]
	1[illegible].0	[illegible]	+ [illegible]	70	0.250	"				0.20	
	1[illegible].0	[illegible].3	+ [illegible]	[illegible]	0.250	"				0.35	
	1[illegible]	[illegible].2	+ [illegible]	70	0.250	"				0.35	
	135.0	[illegible]	+ [illegible].9	72	0.250	Test	in Progress			0.50	.[illegible]0
	1[illegible].0	[illegible]	+ [illegible]	[illegible]	0.2[illegible]0	"		"		0.[illegible]	
	13[illegible]	[illegible]	+ [illegible]	58	0.2[illegible]	"		"		0.[illegible]	
	13[illegible]	[illegible]	+ 1[illegible]	[illegible]	0.265	"		"		0.70	
	1[illegible].0	20.[illegible]	+ [illegible]	[illegible]	.5[illegible]	0.1	Non-Plastic			0.1	.[illegible]-.1
	1[illegible]7.0	[illegible]	+ [illegible]	[illegible]	0.5[illegible]	[illegible].05		"		0.13	
	107.0	[illegible].0	+ [illegible]	[illegible]	0.5[illegible]	[illegible].2		"		0.15	
	107.0	21.1	+ [illegible]	[illegible]	[illegible].7[illegible]	[illegible]		"		0.20	
	1[illegible]	20.[illegible]	- 1.5	[illegible]	.5[illegible]	[illegible].1	Non-Plastic			[illegible]	.30
	1[illegible]	2[illegible]	+ [illegible]		.[illegible]	[illegible]		"		0.05	
	1[illegible]	2[illegible]	- 1.[illegible]		[illegible]	[illegible]		"		.0.0[illegible]	
	1[illegible]	[illegible]	+ [illegible]	[illegible]	0.[illegible]	[illegible].[illegible]8		"		0.1[illegible]	
	11[illegible].0	17.[illegible]	+ [illegible]	[illegible]	.465	1.17	Non-Plastic			0.10	.[illegible]-.[illegible]
	1[illegible].0	1[illegible]	+ [illegible]	[illegible]	[illegible]	0.7[illegible]		"		0.1[illegible]	
	1[illegible]	[illegible]	+ [illegible]	[illegible]	.[illegible]	[illegible]		"		0.10	
	1[illegible].0	16.8	+ [illegible].5	[illegible]	[illegible]	0.[illegible]		"		0.2[illegible]	

[illegible] [illegible] [illegible] [illegible] [illegible] (3) Based on the penetration of 32 degree Fahrenheit temperature.

[illegible] [illegible], [illegible]

B

[illegible]	PERCENT STONES >2.0 mm.	VOID RATIO e	PERMEABILITY K x 10^-4 (cm/sec.)	ATTERBERG LIMITS Minus #40 Sieve			MAXIMUM RATE OF HEAVE cm./day	RANGE OF RATE OF FROST PEN. AT MAX. RATE OF HEAVE (inches/day) (3)	TEMPERATURE AT BOUNDARY OF FROZEN AND UNFRO-ZEN SOIL
				L.L.	P.L.	P.I.			
	67	0.240	4.9	Test in Progress			0.15	.10-.30	-
	65	0.240	2.35		"		0.25		
	69	0.240	0.2		"		0.30		
	66	0.240	0.07	25.3	18.3	7.0	0.40		
	67	0.370	Test in Progress				0.20	.15	31.6°
	67	0.400					0.15		
	67	0.235	"				0.35		
	67	0.235	"				[illegible]		
	70	0.250	Test in Progress				0.20	-.20-.45	31.[illegible]
	70	0.250	"				0.20		
	[illegible]	0.250	"				0.35		
	70	0.250	"				0.35		
	72	0.250	Test in Progress				0.50	.40	30.8
	[illegible]	0.260	"		"		0.55		
	58	[illegible]	"		"		0.44		
	[illegible]	0.255	"		"		0.70		
	[illegible]	[illegible]	[illegible].1	Non-Plastic			0.1[illegible]	.[illegible]-.15	—
	[illegible]	[illegible]	[illegible]		"		0.35		
	[illegible]	[illegible]	4.2		"		0.15		
	[illegible]	[illegible]	[illegible]		"		[illegible]		
	[illegible]	[illegible]	[illegible].1	Non-Plastic			0.05	.30	[illegible]
		[illegible]	[illegible]		"		0.05		
		[illegible]	[illegible]		"		0.05		
	[illegible]	[illegible]	[illegible]		"		0.1[illegible]		
	[illegible]	[illegible]	1.17	Non-Plastic			0.10	.[illegible]-.5[illegible]	[illegible]
	[illegible]	[illegible]	2.7[illegible]		"		0.15		
	[illegible]	[illegible]	[illegible]		"		0.10		
	[illegible]	[illegible]	[illegible]		"		0.25		

(3) Based on the penetration of 32 degree Fahrenheit temperature.

SAMPLE NUMBER	SOIL	% < .02 mm. BY WEIGHT	COMBINED SPECIFIC GRAVITY	ORIGINAL HEIGHT (inches)	THICKNESS OF FROZEN PORTION (inches)	HEAVE (inches)	HEAVE (%) (1)	[illegible]
AG1-1	Peabody, Mass. Sand and	[illegible]	2.70	6.00	[illegible]	[illegible]	[illegible]	[illegible]
AG1-2	Gravel blended with	[illegible]	2.70	6.00	5.50	[illegible]	[illegible]	[illegible]
AG1-3	New Hampshire silt	[illegible]	2.70	6.00	[illegible]	[illegible]	[illegible]	[illegible]
AG1-4	1 " max. size)	[illegible]	2.70	[illegible]	3.27	[illegible]	[illegible]	[illegible]
AG1-5	Peabody, Mass. Sand	[illegible]	2.70	[illegible]	[illegible]	[illegible]	11.4	134
AG1-6	and Gravel blended	[illegible]	2.71	[illegible]	-	0.65	10.6	[illegible]
AG1-7	with East Boston Till	[illegible]	[illegible]	5.65	-	[illegible]	11.0	[illegible]
AG1-8	(1" max. size)	10	2.71	[illegible]	-	[illegible]	11.0	[illegible]
AG2-1	Peabody, Mass. Sand	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.1	[illegible]
AG2-6	and Gravel blended	[illegible]	.70	[illegible]	-	[illegible]	7.3	[illegible]
AG2-7	with New Hampshire	[illegible]	2.70	6.00	-	[illegible]	[illegible]	[illegible]
AG2-8	Silt (1" max. size	[illegible]	2.70	6.00	[illegible]	[illegible]	[illegible]	[illegible]
LS-1	Lowell Sand blended	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
LS-2	with East Boston	[illegible]	[illegible]	.00	[illegible]	[illegible]	[illegible]	104.
LS-3	Till	[illegible]	2.69	6.00	-	[illegible]	[illegible]	104.
LS-4	"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	104.
NH-1	New Hampshire Silt	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
NH-2	"	90	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
NH-3	"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
NH-4	"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
EBT-1	East Boston Till	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
EBT-2	"	[illegible]	[illegible]	6.00	[illegible]	[illegible]	[illegible]	120.
EBT-3	"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
EBT-4	"	[illegible]	[illegible]	6.00	0.64	2.56	[illegible]	[illegible]
LF-1	Loring AFB (Gravelly)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	83.
LF-2	"	[illegible]	2.74	6.00	[illegible]	[illegible]	[illegible]	[illegible]
LF-3	"	[illegible]	[illegible]	6.04	[illegible]	[illegible]	29.5	[illegible]
LF-4	"	[illegible]	2.74	5.10	1.00	1.96	36.5	[illegible]
[illegible]	[illegible] Blue Clay	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	"	[illegible]	[illegible]	.98	1.82	[illegible]	[illegible]	[illegible]
[illegible]	"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	"	[illegible]	.72	[illegible]	[illegible]	[illegible]	[illegible]	79.

(1) Based on [illegible] of frozen portion, before [illegible].

2 [illegible]

SUMMARY OF [illegible]

[illegible]	[illegible] DENSITY (lbs/ft³)	[illegible] % DRY WEIGHT: BEFORE FREEZING (2)	[illegible] % DRY WEIGHT: [illegible]	[illegible] > 0.[illegible] mm.	VOID RATIO	PERMEABILITY [illegible] x 10⁻⁴ [illegible]	ATTERBERG LIMITS MINUS #40 SIEVE: L.L.	ATTERBERG LIMITS MINUS #40 SIEVE: P.L.	ATTERBERG LIMITS MINUS #40 SIEVE: P.I.	MAXIMUM RATE OF HEAVE (mm/day)	[illegible] OF FROST [illegible] MAX. [illegible] OF HE[illegible] (inches)
.35	[illegible]	13.7	- [illegible]	[illegible]	0.370	[illegible]	Tests in Progress			[illegible]	.[illegible]-
.3	[illegible]	12.5	- [illegible]	[illegible]	[illegible]	[illegible]		"		[illegible]	
.3	[illegible]	11.9	- [illegible]	[illegible]	[illegible]	[illegible]		"		0.10	
.3	[illegible]	[illegible]	- [illegible]	[illegible]	.370	[illegible]		"		[illegible]	
[illegible]	[illegible]	[illegible]	+ [illegible]	[illegible]	0.270	Tests in Progress				[illegible]	.10-
[illegible]	[illegible]	[illegible]	+ [illegible]	[illegible]	[illegible]	"		"		[illegible]	
[illegible]	134.2	[illegible]	+ [illegible]	[illegible]	[illegible]	"		"		0.25	
[illegible]	13[illegible].2	[illegible].5	+ [illegible]	[illegible]	[illegible]	"	[illegible]	[illegible]	[illegible]	[illegible]	
1	[illegible]	[illegible]	- [illegible]	[illegible]	[illegible]	Tests in Progress				[illegible]	.00-[illegible]
[illegible]	127.0	[illegible]	+ [illegible]	[illegible]	[illegible]	"				0.15	
[illegible]	[illegible]	11.[illegible]	+ [illegible]	33	[illegible]	"				[illegible]	
[illegible]	[illegible]	[illegible]	+ [illegible]	[illegible]	[illegible]	"	Non-Plastic			0.20	
[illegible]	[illegible]	22.[illegible]	- [illegible]	[illegible]	[illegible]	[illegible]				[illegible]	.05-[illegible]
[illegible]	10[illegible]	22.[illegible]	- [illegible]	[illegible]	[illegible]	[illegible]				[illegible]	
[illegible]	10[illegible]	22.[illegible]	- [illegible]	0	[illegible]	[illegible]				0.05	
[illegible]	10[illegible]	[illegible].5	- [illegible]	[illegible]	[illegible]	[illegible]	Non-Plastic			0.10	
[illegible]	[illegible]	[illegible]	+ [illegible]	[illegible]	[illegible]	[illegible].76	26.[illegible]	26.5	[illegible].1	[illegible]	.[illegible]
[illegible]	[illegible]	28.[illegible]	+ 28.[illegible]	[illegible]	[illegible]	[illegible]		"		[illegible]	
[illegible]	[illegible]	[illegible].2	+ [illegible]		[illegible]	[illegible]		"		[illegible]	
[illegible]	[illegible]	[illegible]	+ [illegible]	[illegible]	[illegible]	.245		"		[illegible]	
[illegible]	[illegible]	[illegible]	+ [illegible]	2[illegible]	.500	0.11	22.6	[illegible]	7.[illegible]	1.[illegible]	.[illegible]
[illegible]	120.0	15.[illegible]	+ [illegible]	2[illegible]	[illegible]	[illegible]		"		1.30	
[illegible]	[illegible]	[illegible]	+ [illegible]	2[illegible]	[illegible]	[illegible]		"		[illegible]	
.7	[illegible]	11.7	+ [illegible]	2[illegible]	[illegible]	[illegible]28		"		[illegible]	
[illegible]	83.[illegible]	[illegible]	+ [illegible]	[illegible]	[illegible]	[illegible]	[illegible].6	[illegible]	[illegible]	[illegible]	.20-[illegible]
[illegible]	[illegible]	[illegible]	+ [illegible]		[illegible]	[illegible]		"		0.15	
.5	[illegible]	[illegible]	+ [illegible]	[illegible]	[illegible]	[illegible]		"		[illegible].20	
.5	[illegible]	[illegible]	+ [illegible]	[illegible]	[illegible]	[illegible]		"		[illegible]	
[illegible]	[illegible]	[illegible].2	+ [illegible]	[illegible]	1.0[illegible]	Tests in Progress	[illegible]	21.7	21.6	[illegible].5	-
[illegible]	[illegible]	[illegible]	+ [illegible]	[illegible]	1.02[illegible]	"		"		[illegible]	
[illegible]	[illegible]	[illegible].5	- [illegible]	[illegible]	[illegible]	"		"		0.30	
[illegible]	[illegible].1	[illegible]	- [illegible]	[illegible]	[illegible]	"		"		0.60	

[illegible] conditions [illegible], whichever [illegible]

[illegible] Based on the penetration of 32 degree Fahrenheit temperature.

B

[illegible]	[illegible] Stone [illegible]	Void Ratio	[illegible]	Attrition [illegible] (1)			[illegible] Rate [illegible]	[illegible] (in per sec) (5)	[illegible]
				[illegible]	[illegible]	[illegible]			
[illegible]	[illegible]	[illegible].370	[illegible]	Tests In Progress			[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	Tests In Progress				[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	Tests In Progress				[illegible]	[illegible]	[illegible]
				Non-Testable					
[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	[illegible]
				Non-Testable					
[illegible]	[illegible]	[illegible]	.70, [illegible], .245	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	22.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	Tests In Progress	[illegible]	21.7	21.6	[illegible]	-	[illegible]

[illegible] the Penetration of [illegible] Degree Pavement [illegible].

SAMPLE NUMBER	SOIL	PERCENT < 0.02 mm. BY WEIGHT	COMBINED SPECIFIC GRAVITY	ORIGINAL HEIGHT (inches)	THICKNESS OF UNFROZEN PORTION (inches)	HEAVE (inches)	PERCENT HEAVE (%)
TD-1	Truax AFB (base and	2	[illegible]	[illegible]	-	[illegible]	[illegible]
TD-2	subbase)	[illegible]	2.70	[illegible]	-	[illegible]	[illegible]
TD-3		[illegible]	[illegible]	[illegible]	-	[illegible]	[illegible]
TD-4		13	2.70	[illegible]	[illegible]	[illegible]	[illegible]
TD-5	Truax AFB (base and	16	[illegible]	[illegible]	-	[illegible]	[illegible]
TD-6	subbase)	22	[illegible]	[illegible]	-	[illegible]	[illegible]
CA-1	Casper AFB (base)	16	[illegible]	[illegible]	-	[illegible]	[illegible]
PA-1	Pierre Airfield (base)	9	[illegible]	[illegible]	-	[illegible]	[illegible]
LA-1	Lowry AFB (subgrade)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
LA-2	" "	31	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CA-2	Casper AFB (subgrade)	[illegible]	[illegible]	[illegible]	-	[illegible]	[illegible]
CA-3	Casper AFB (base)	[illegible]	[illegible]	[illegible]	-	[illegible]	[illegible]
FA-1	Fargo AFB (base)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
WN-1	Wendover AFB (base)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SF-1	Sioux Falls (base)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
RC-1	Rapid City AFB (base)	[illegible]	[illegible]	[illegible]	-	[illegible]	[illegible]
[illegible]	[illegible] Field [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Patterson Field (base)	[illegible]	[illegible]	[illegible]	-	[illegible]	[illegible]
[illegible]	Clinton County AFB (base)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Spokane AFB (base)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible] of frozen [illegible]

SUMMARY OF [illegible] DATA

PERCENT HEAVE (1)	DRY DENSITY (lbs ft³)	WATER CONTENT % DRY WEIGHT BEFORE FREEZING (2)	WATER CONTENT % DRY WEIGHT GAIN [illegible]	[illegible] > [illegible]	VOID RATIO e	PERMEABILITY k x 10⁻ cm/sec	ATTERBERG LIMITS MINUS #40 SIEVE L.L.	P.L.	P.I.	MAXIMUM [illegible]	[illegible]
[illegible].7	[illegible]	12.[illegible]	+ [illegible]	13	[illegible]	Test in Progress	Non-Plastic			.1	
8.[illegible]	127.[illegible]	[illegible]	+ [illegible]	17	[illegible]					[illegible]	
17.[illegible]	[illegible]	[illegible]	+ [illegible]	[illegible]	[illegible]					[illegible]	
1[illegible].2	[illegible]	[illegible]	+ [illegible]	[illegible]	[illegible]					[illegible]	
3.2	[illegible]	[illegible].2	+ [illegible]	[illegible]	[illegible]		[illegible]			[illegible]	
[illegible].2	[illegible]	[illegible]	+ [illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	
[illegible].7	117.[illegible]	[illegible]	+ [illegible].5	[illegible]	[illegible]	[illegible]	21.	[illegible]	[illegible]	[illegible]	
[illegible]	12[illegible]	[illegible]	+ [illegible]	[illegible]3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	+ [illegible].7	[illegible]	[illegible]70	[illegible]	[illegible]	[illegible]		[illegible]	
[illegible]	[illegible]	[illegible]	+ [illegible]	[illegible]	[illegible]	[illegible].31	2[illegible]	[illegible].7	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	+ [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	+ [illegible]	[illegible]	[illegible]	[illegible]	2[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	+ [illegible]	[illegible]	[illegible]	[illegible]	[illegible].7	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	+ [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	+ [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	+ [illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	+ [illegible]		[illegible]	[illegible]	Non-Plastic			[illegible]	
[illegible]	[illegible]	[illegible]	+ [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible].1	[illegible]	
[illegible]	[illegible]	[illegible]	+ [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	+ [illegible]	[illegible]	[illegible]	[illegible]	Non-Plastic			[illegible]	

[illegible] condition [illegible]

[illegible] water [illegible] level [illegible]

B

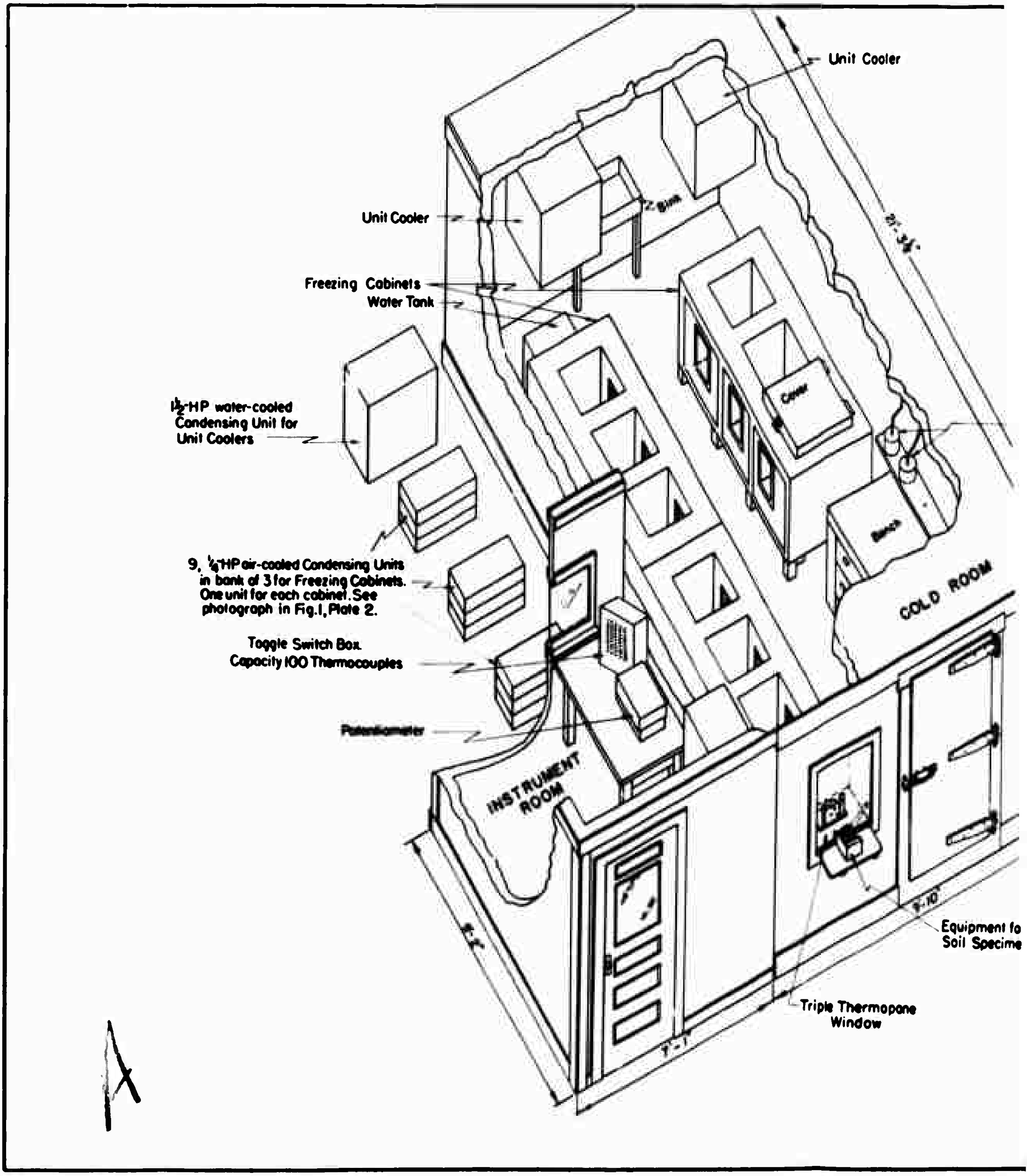
[illegible]	Percent finer > 0.02 mm	Void ratio e	Permeability k at 20°C cm/sec	Atterberg limits, minus No. 40 sieve: L.L.	P.L.	P.I.	Maximum rate of heave mm/day	Range of rate of frost pen. at max. rate of heave	Temperature at boundary of frozen and unfrozen soil
[illegible]	13	[illegible]	Test in Progress	Non-Plastic			.1	.[illegible]	-
[illegible]	17	0.[illegible]	"	"			[illegible].15		
[illegible]	1[illegible]	[illegible].2[illegible]	"	"			.[illegible]		
[illegible]	1[illegible]	0.2[illegible]	"	"			.[illegible]		
[illegible]	1[illegible]	[illegible].400	"	Test in Progress			0.2[illegible]	.[illegible]-.[illegible]	-
[illegible]	1[illegible]	[illegible]	"	1[illegible]	1[illegible]	[illegible].6	0.20		
[illegible]	[illegible]	0.40[illegible]	1.[illegible]	21.	[illegible]	[illegible]	.[illegible]		
[illegible]	[illegible]3	0.38[illegible]	[illegible]	2[illegible].	[illegible]	7.	[illegible]		
	1	[illegible].470	[illegible]	[illegible]	[illegible]	[illegible]	.[illegible]	.[illegible]5	31.5
	[illegible]	[illegible].[illegible]	[illegible].31	2[illegible]	1[illegible].7	[illegible]	[illegible]		
	[illegible]	[illegible]	[illegible]	[illegible]	1[illegible]	[illegible]	[illegible]		
	1[illegible]	[illegible]	[illegible]	2[illegible]	[illegible]	[illegible].6	[illegible]		
	[illegible]	[illegible]	[illegible]	[illegible].7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
		[illegible]	[illegible]	Non-Plastic			[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.1	[illegible]		
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
	[illegible]	[illegible]	[illegible]	Non-Plastic			[illegible]		

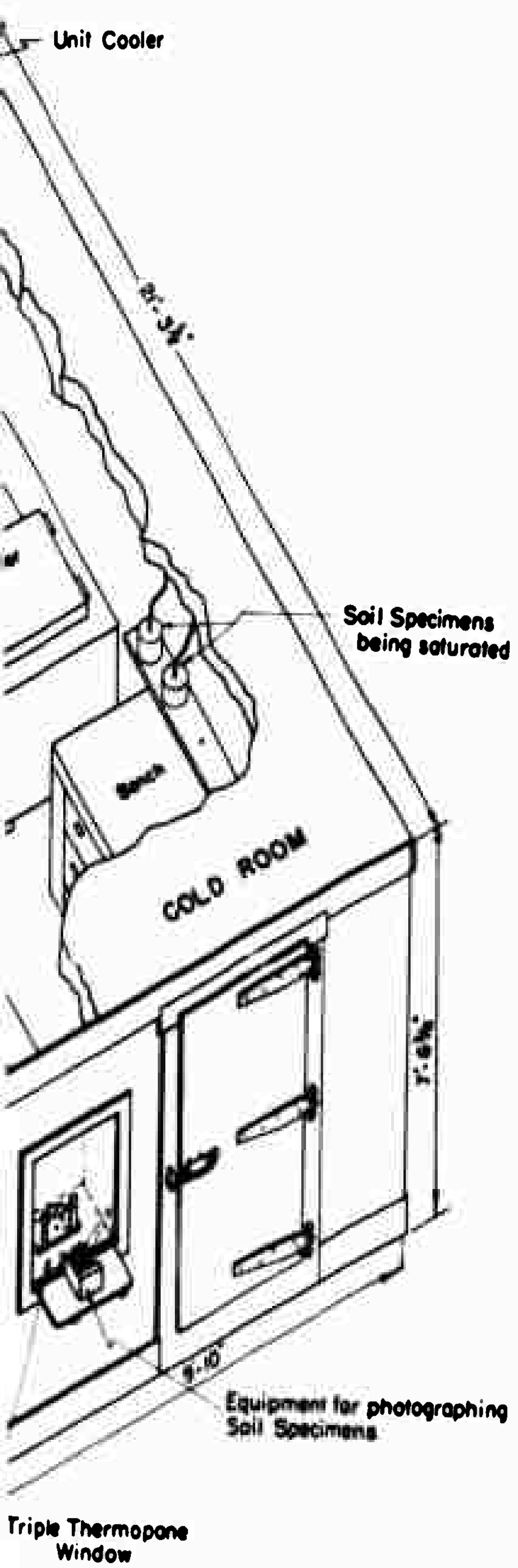
INTERIM REPORT
OF
COLD ROOM STUDIES

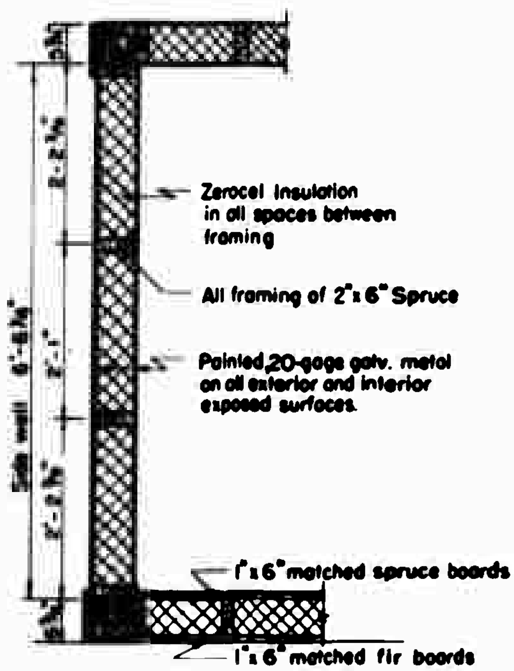
DEGREE OF SATURATION IN SPECIMENS AT START OF TEST

Sample No.	% Saturation	Sample No.	% Saturation	Sample No.	% Saturation
LSG-1	100	AG1-1	100	BC-1	100
LSG-2	100	AG1-2	94	BC-2	100
LSG-3	98	AG1-3	87	BC-5	100
LSG-4	100	AG1-4	91	BC-6	100
LSG-5	91	AG1-5	100	TD-1	96
LSG-6	96	AG1-6	94	TD-2	100
LSG-7	100	AG1-7	91	TD-3	98
LSG-8	97	AG1-8	89	TD-4	100
LSG-9	100	AG2-5	98	TD-5	92
LSG-10	93	AG2-6	91	TD-6	94
LSG-11	100	AG2-7	97	CA-1	100
LSG-12	95	AG2-8	86	PA-1	100
LSG-13	99	LS-1	99	LA-1	100
LSG-14	97	LS-2	100	LA-2	97
LSG-15	92	LS-3	99	CA-2	95
LSG-16	98	LS-4	99	CA-3	100
MFS-1	100	NH-1	100	FA-1	100
MFS-2	100	NH-2	100	WN-1	100
MFS-3	100	NH-3	100	SF-1	100
MFS-4	100	NH-4	100	RC-1	99
MFS-5	99	EBT-1	100	HF-1	96
MFS-6	100	EBT-2	100	PT-1	100
MFS-7	99	EBT-3	100	CL-1	100
MFS-8	95	EBT-4	100	SPK-1	100
MFS-9	100	LF-1	98		
MFS-10	96	LF-2	96		
MFS-11	100	LF-3	100		
MFS-12	97	LF-4	100		

TABLE 2


Unit Cooler
Unit Cooler
Sink
Freezing Cabinets
Water Tank
1½-HP water-cooled Condensing Unit for Unit Coolers
9, ¼HP air-cooled Condensing Units in bank of 3 for Freezing Cabinets. One unit for each cabinet. See photograph in Fig.1, Plate 2.
Toggle Switch Box. Capacity 100 Thermocouples
Potentiometer
Cooler
Bench
COLD ROOM
INSTRUMENT ROOM
Equipment fo
Soil Specime
Triple Thermopane Window





TYPICAL SECTION
THROUGH COLD ROOM

SCALE IN FEET

FROST INVESTIGATION 1949-1950

COLD ROOM STUDIES

VIEW OF COLD ROOM AND EQUIPMENT

FROST EFFECTS LABORATORY
NEW ENGLAND DIVISION CORPS OF ENGINEERS
BOSTON, MASS MAY, 1950

PLATE 1

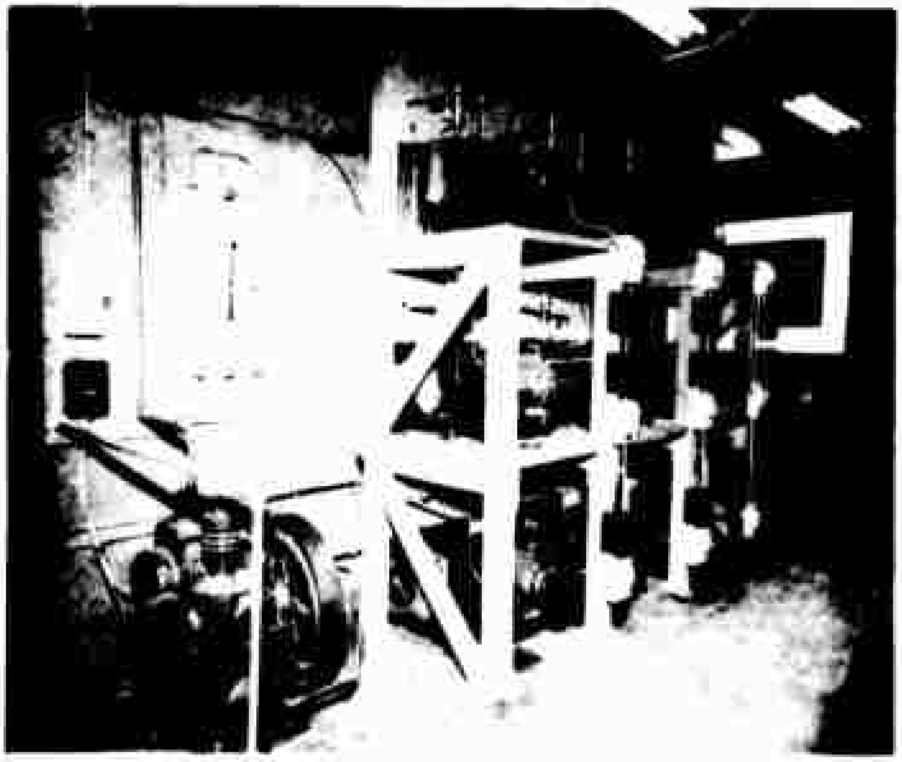


FIG. 1. TEN CONDENSING UNITS FOR THE COLD ROOM AND THE NINE TEST CABINETS.

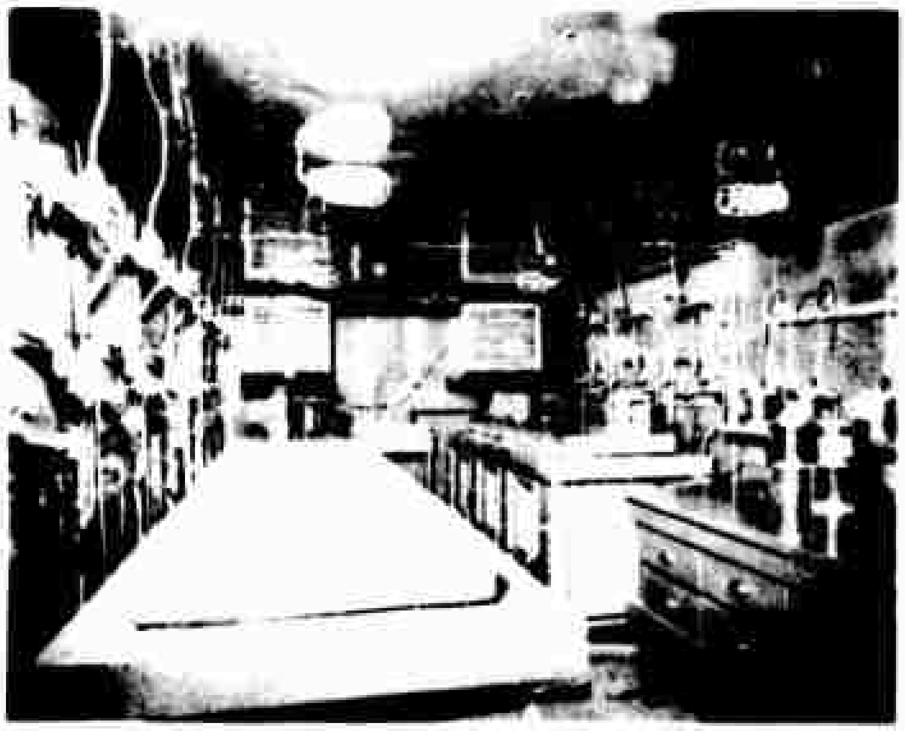


FIG. 2. INSIDE OF COLD ROOM AS SEEN THROUGH THERMOPANE WINDOW. WORKBENCH AND SATURATING EQUIPMENT AT LOWER RIGHT.

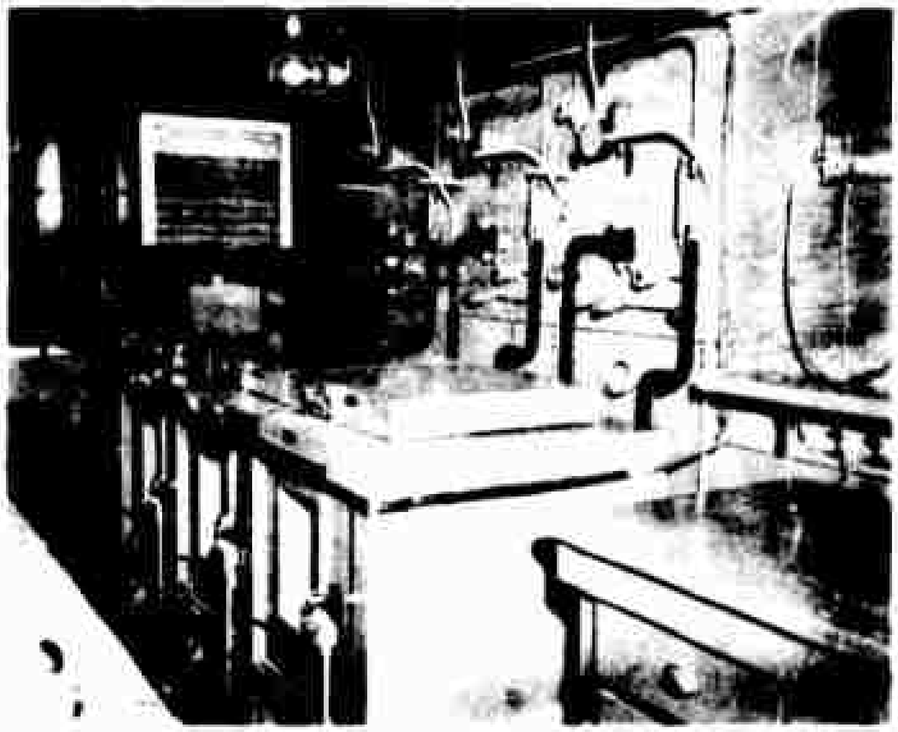


FIG. 1. VIEW OF RIGHT SIDE OF COLD ROOM, AT REAR, SHOWING THREE TEST CABINETS WITH CONSTANT WATER LEVEL DEVICES, THERMOREGULATORS, AND THERMOCOUPLE TERMINAL BOARDS.

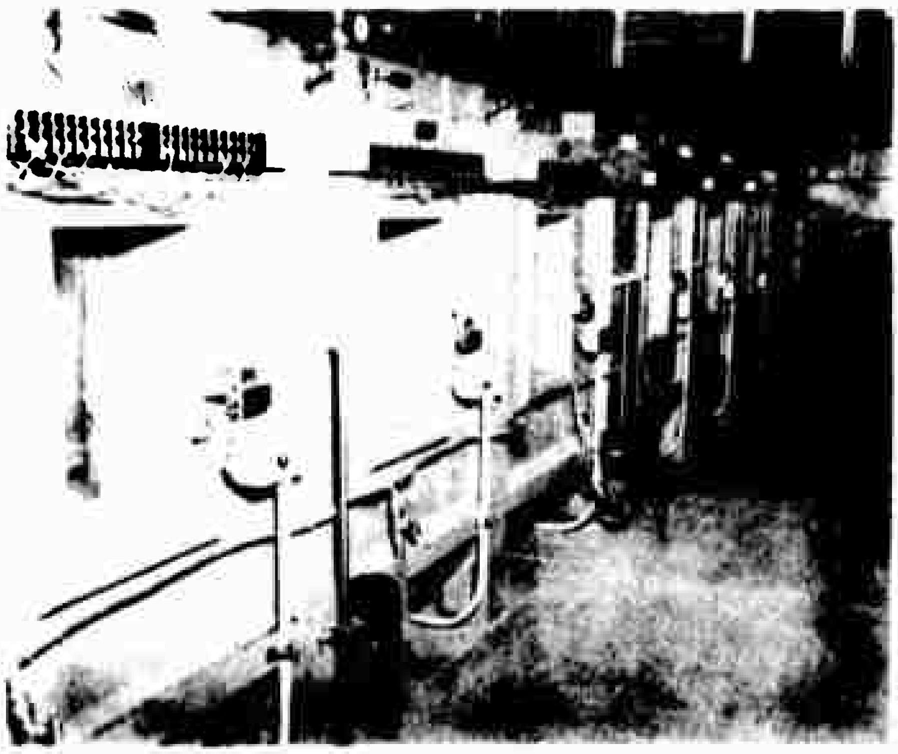


FIG. 2. VIEW OF LEFT SIDE OF COLD ROOM SHOWING SIX TEST CABINETS.

PLATE 3

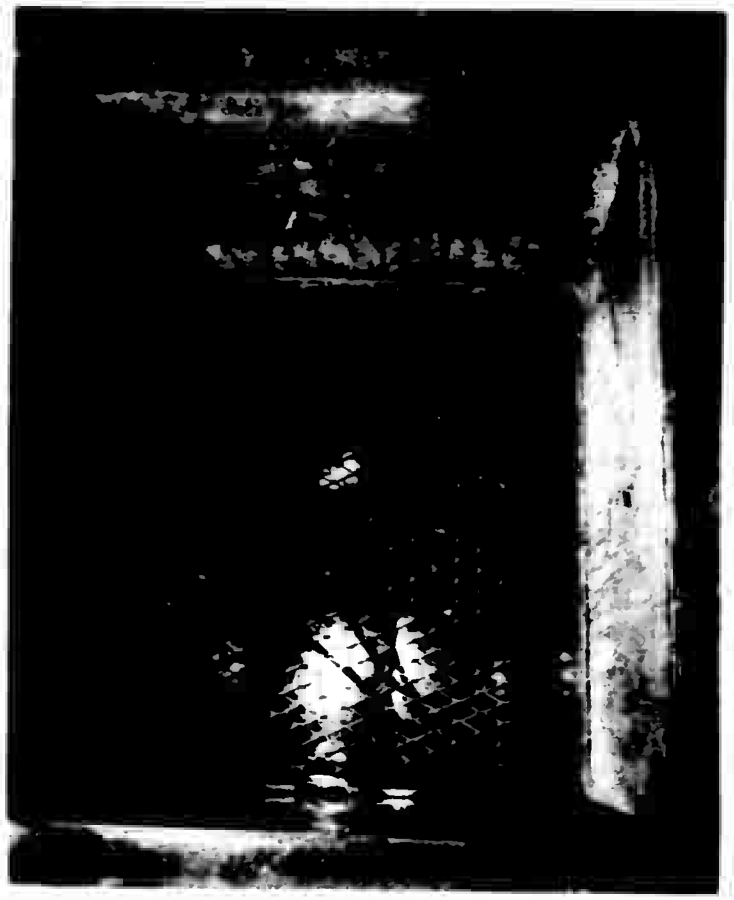
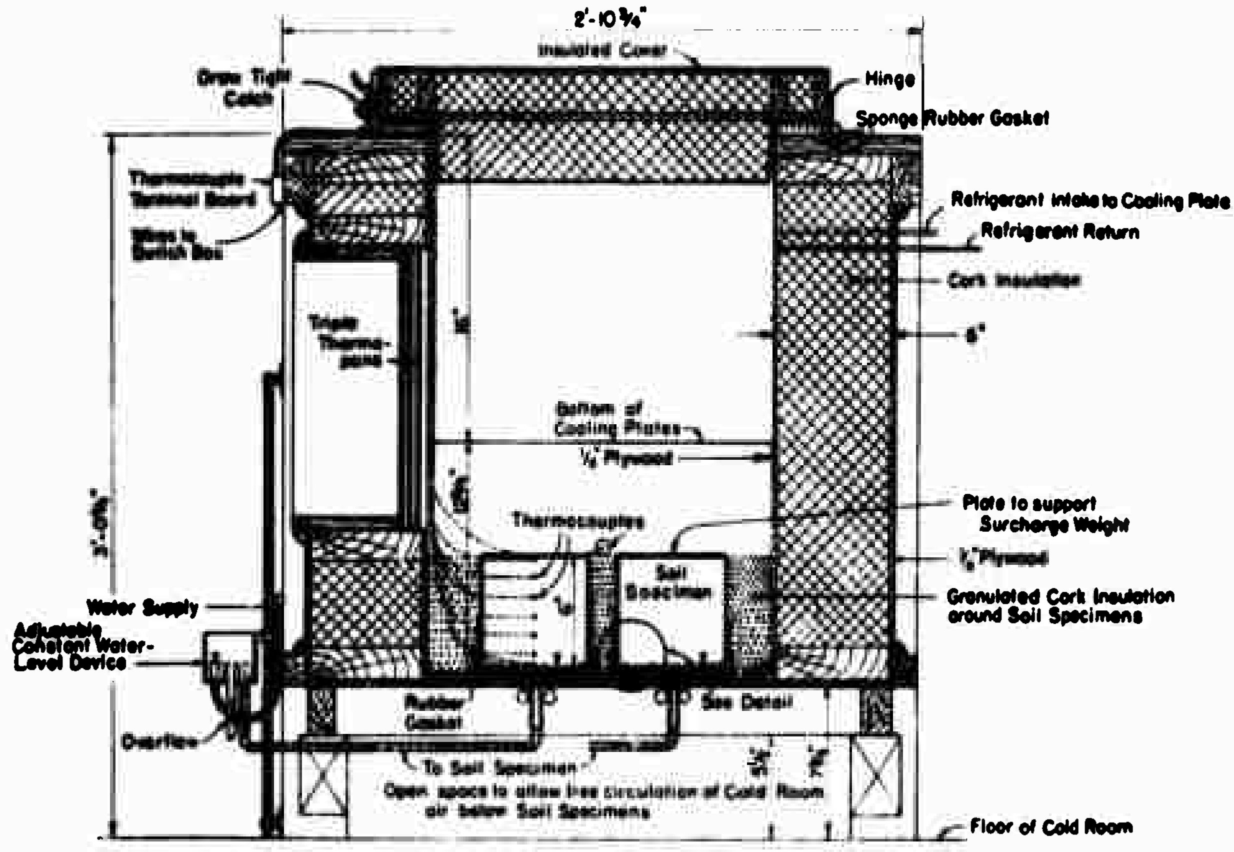


FIG. 1. OPEN GRILL WORK AT BOTTOM OF TEST CABINET FOR SUPPORTING SAMPLES.

FIG. 2. BOTTOM OF TEST CABINET, SHOWING GALVANIZED SHEET METAL OVER GRILL WORK, TOGETHER WITH FOUR SAMPLE RECEPTACLES, OF WHICH TWO ARE EMPTY, ONE HAS POROUS STONE INSERTED, AND ONE IS COMPLETE WITH SOIL SPECIMEN AND SURCHARGE WEIGHTS.

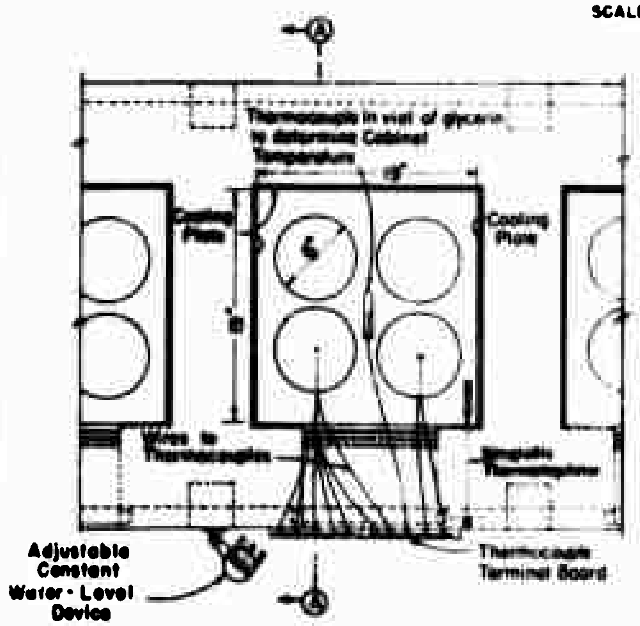
FIG. 1. VIEW INSIDE CABINET SHOWING TWO SOIL SPECIMENS, INSULATED WITH GRANULATED CORK, IN POSITION FOR FREEZING FROM THE TOP.

FIG. 2. TYPICAL SOIL SPECIMEN WITH SURCHARGE WEIGHTS, READY FOR PLACING IN TEST CABINET.



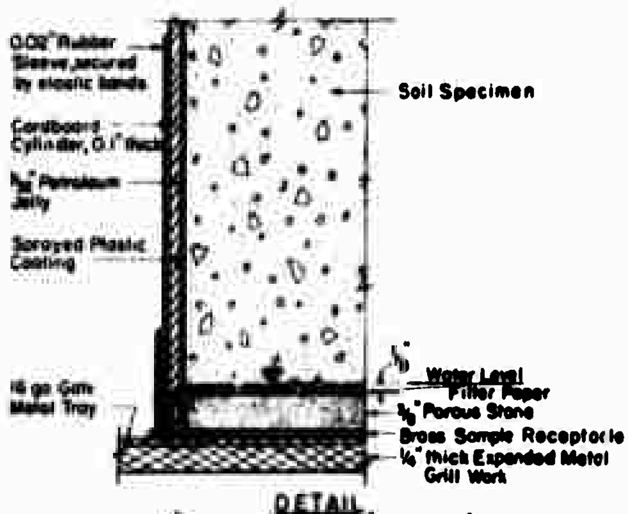
SECTION A-A

0 2" 4" 6" 8" 10" 12" 14" 16"
SCALE IN INCHES



PLAN
(COVERS REMOVED)

0 4" 8" 12" 16" 20"
SCALE IN INCHES



DETAIL

2"
SCALE IN INCHES

***NOTE*:**

This plate shows specific set-up with test samples six inches high and six inches r diameter.

The constant water level device is adjusted to maintain the water level at ⅛" above the porous stone.

FROST INVESTIGATION 1949-1950
COLD ROOM STUDIES

DETAILS OF TEST CABINET AND SAMPLES

FROST EFFECTS LABORATORY
NEW ENGLAND DIVISION — CORPS OF ENGINEERS
BOSTON, MASS. — MAY, 1950

PLATE 6

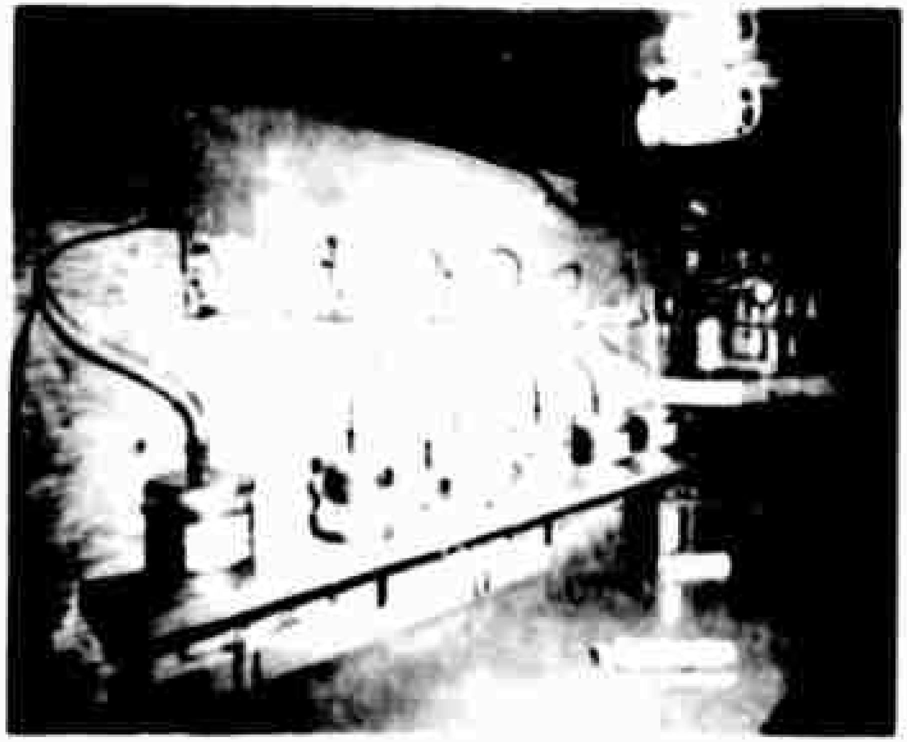


FIG. 1. SOIL SPECIMENS BEING SATURATED IN [illegible] ROOM.

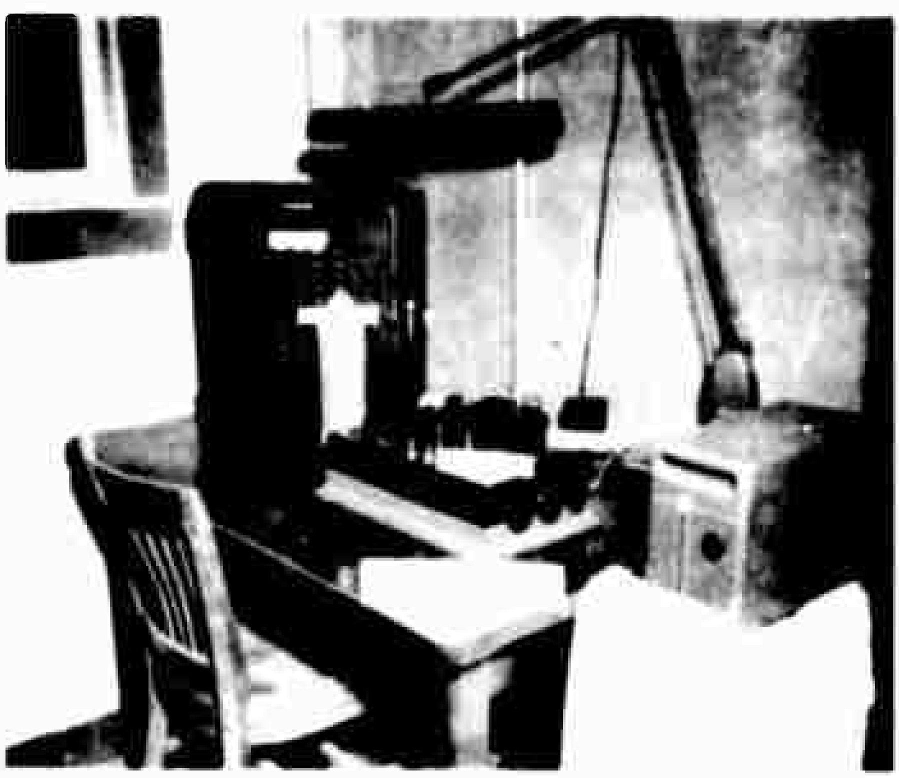


FIG. 2. TEMPERATURE MEASURING EQUIPMENT [illegible] WITH THERMOCOUPLES.

PLATE 7

FIG. 1. VITREOUS CHINA TANK IN COLD ROOM SUPPLYING DE-AIRED WATER TO CONSTANT WATER LEVEL DEVICES.

FIG. 2. SPLIT STEEL MOLDING CYLINDERS, 4.18 INCHES AND 5.92 INCHES IN DIAMETER, RESPECTIVELY. NOTE MOVABLE PISTONS IN CYLINDER ON RIGHT.

PLATE 8

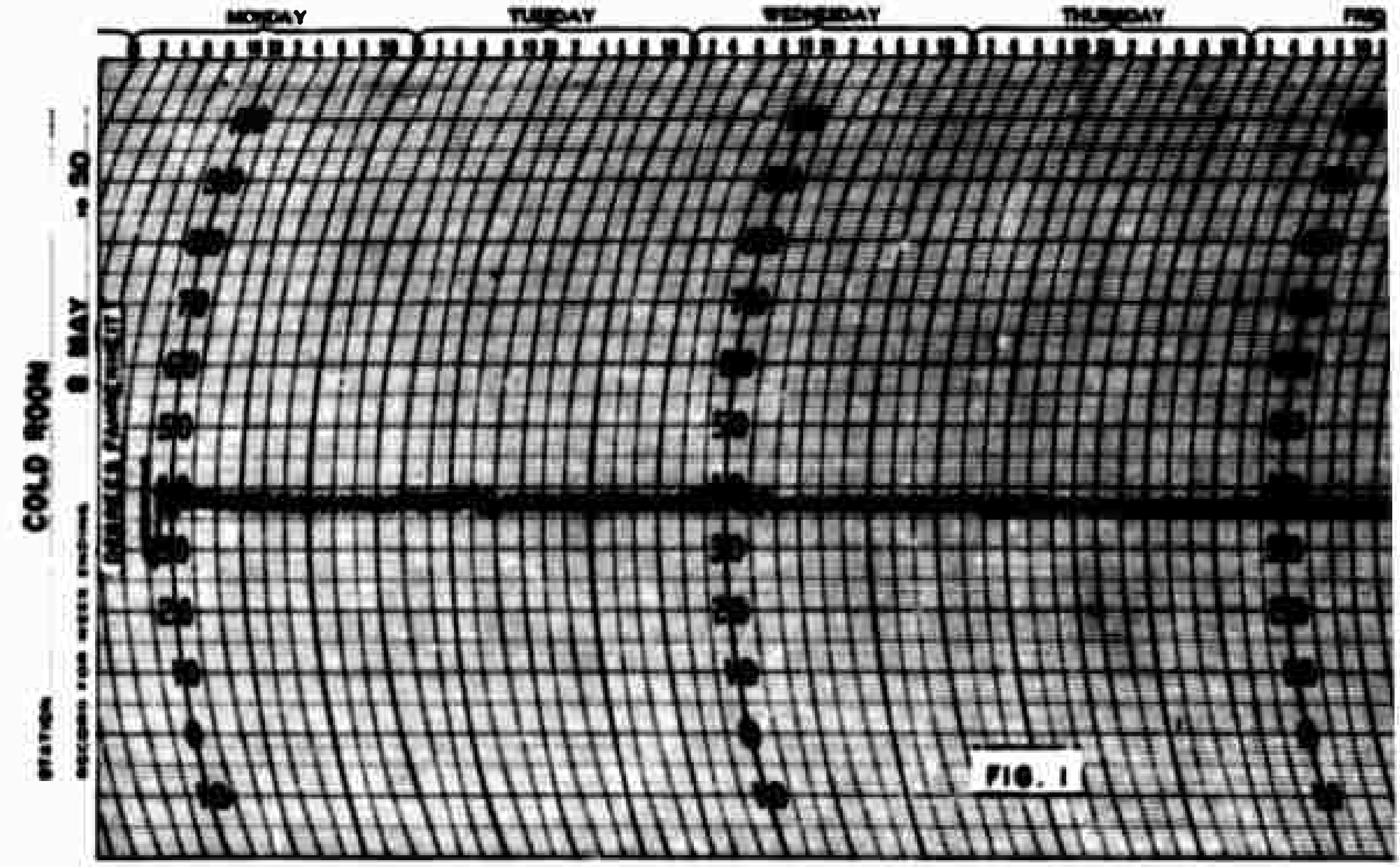

STATION COLD ROOM
RECORD FOR WEEK ENDING 8 MAY 19 50
DEGREES FAHRENHEIT
MONDAY
TUESDAY
WEDNESDAY
THURSDAY

FIG. 1

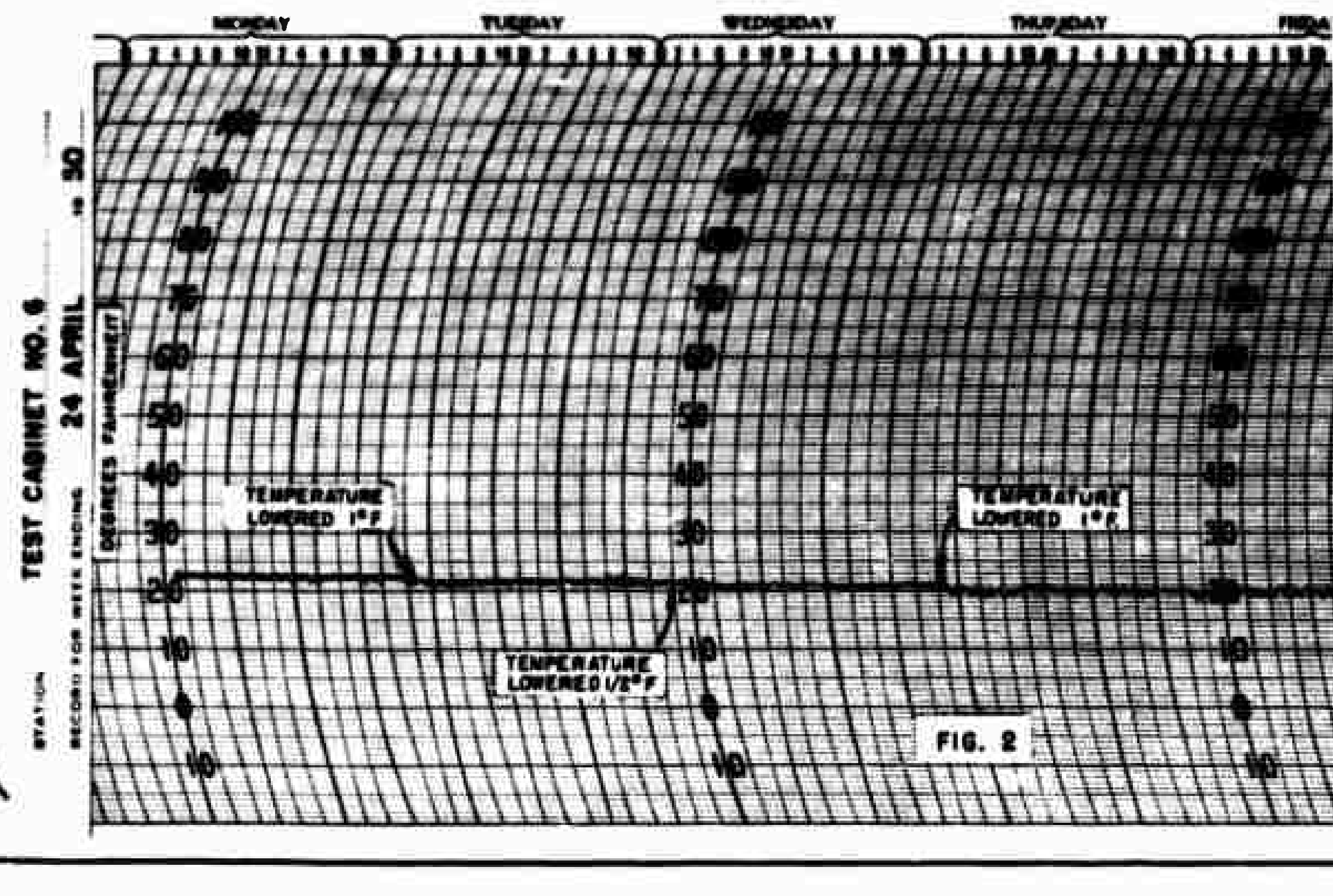
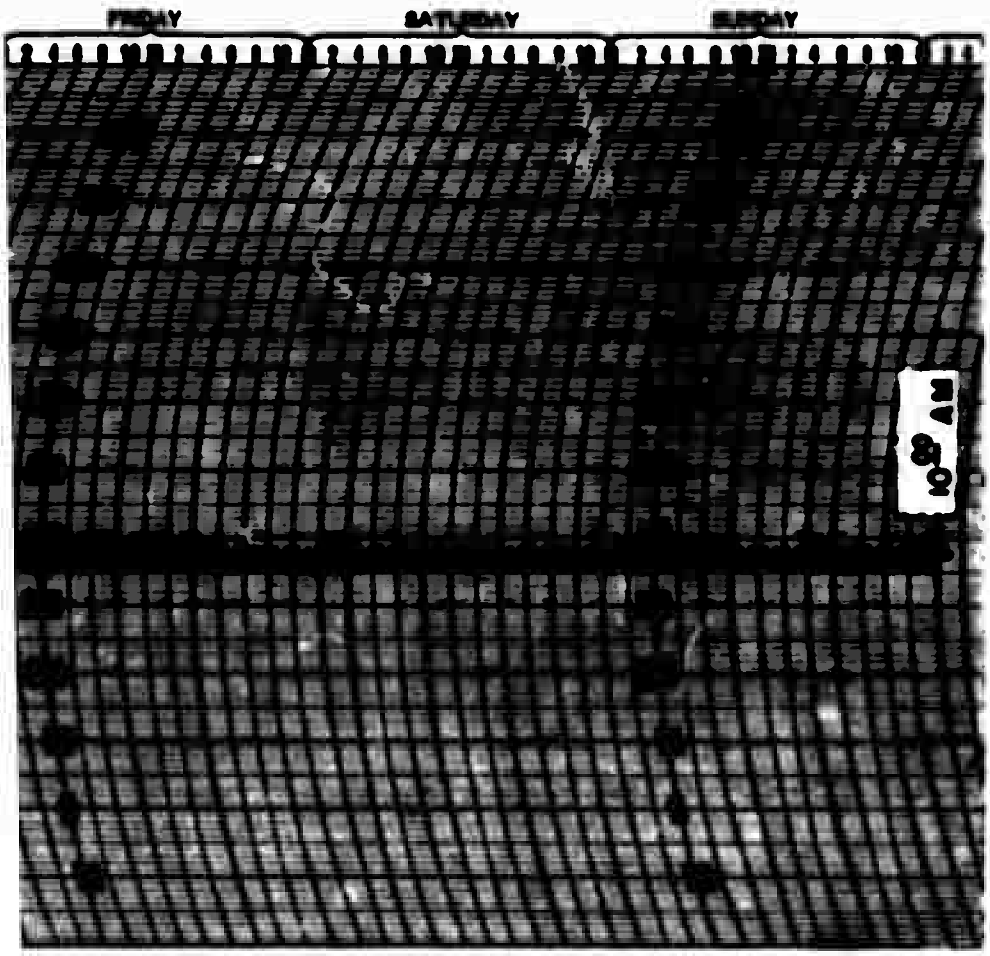
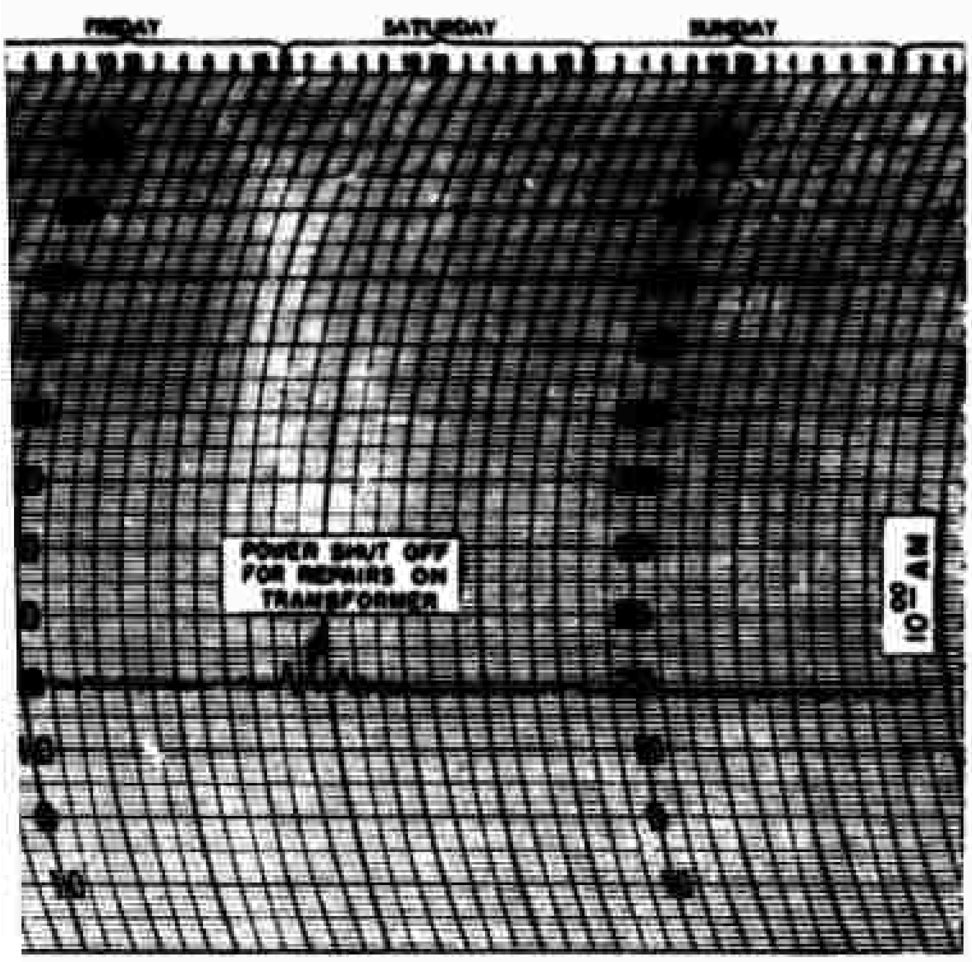

STATION TEST CABINET NO. 6
RECORD FOR WEEK ENDING 24 APRIL 19 50
DEGREES FAHRENHEIT
MONDAY
TUESDAY
WEDNESDAY
THURSDAY
TEMPERATURE LOWERED 1°F
TEMPERATURE LOWERED 1/2°F
TEMPERATURE LOWERED 1°F

FIG. 2





B

FROST INVESTIGATION 1949-1950
COLD ROOM STUDIES

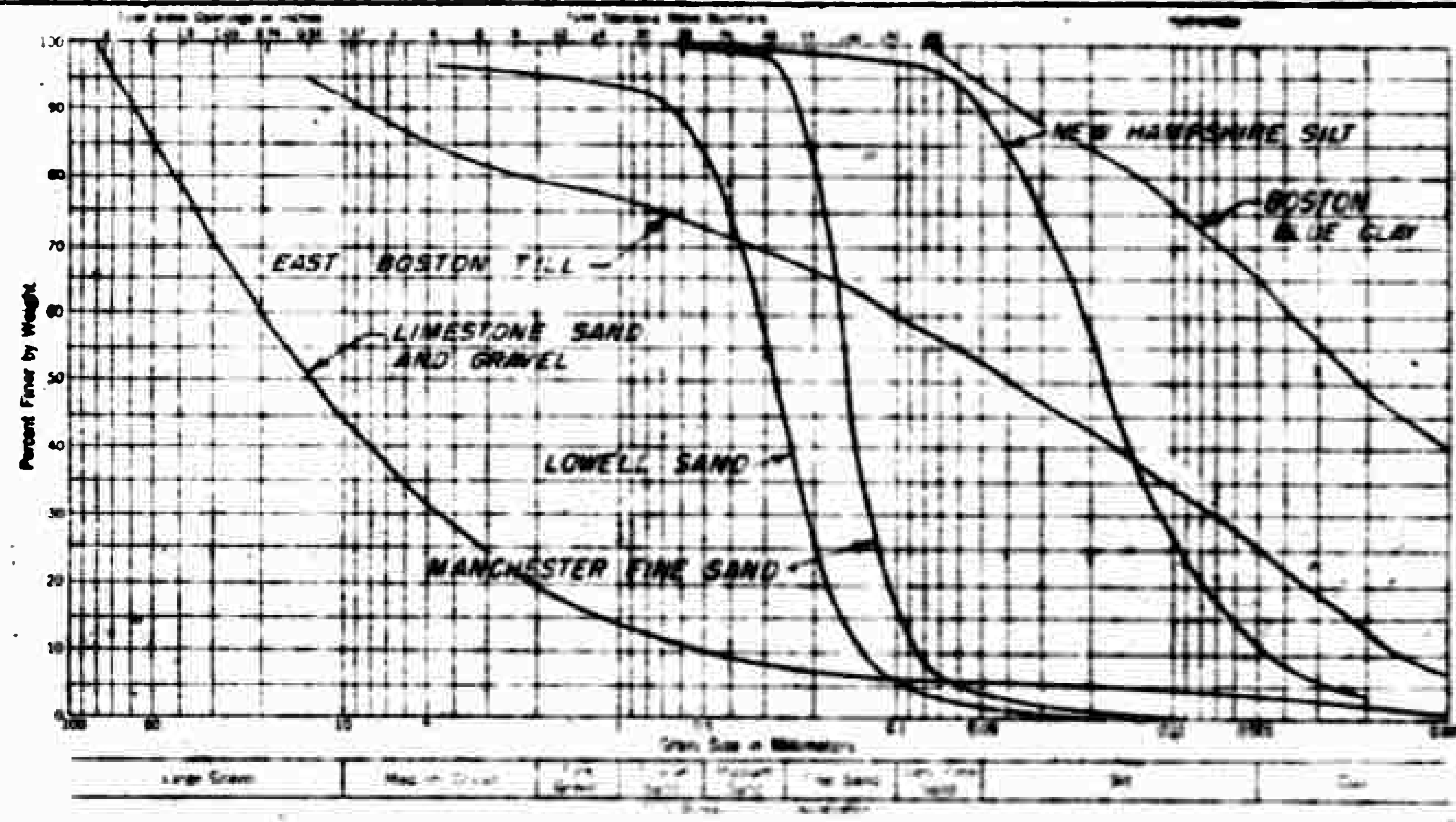
TYPICAL RECORDS OF
COLD ROOM AND TEST CABINET
TEMPERATURES

FROST EFFECTS LABORATORY
NEW ENGLAND DIVISION, CORPS OF ENGRS.
BOSTON, MASS. MAY 1950

PLATE 9

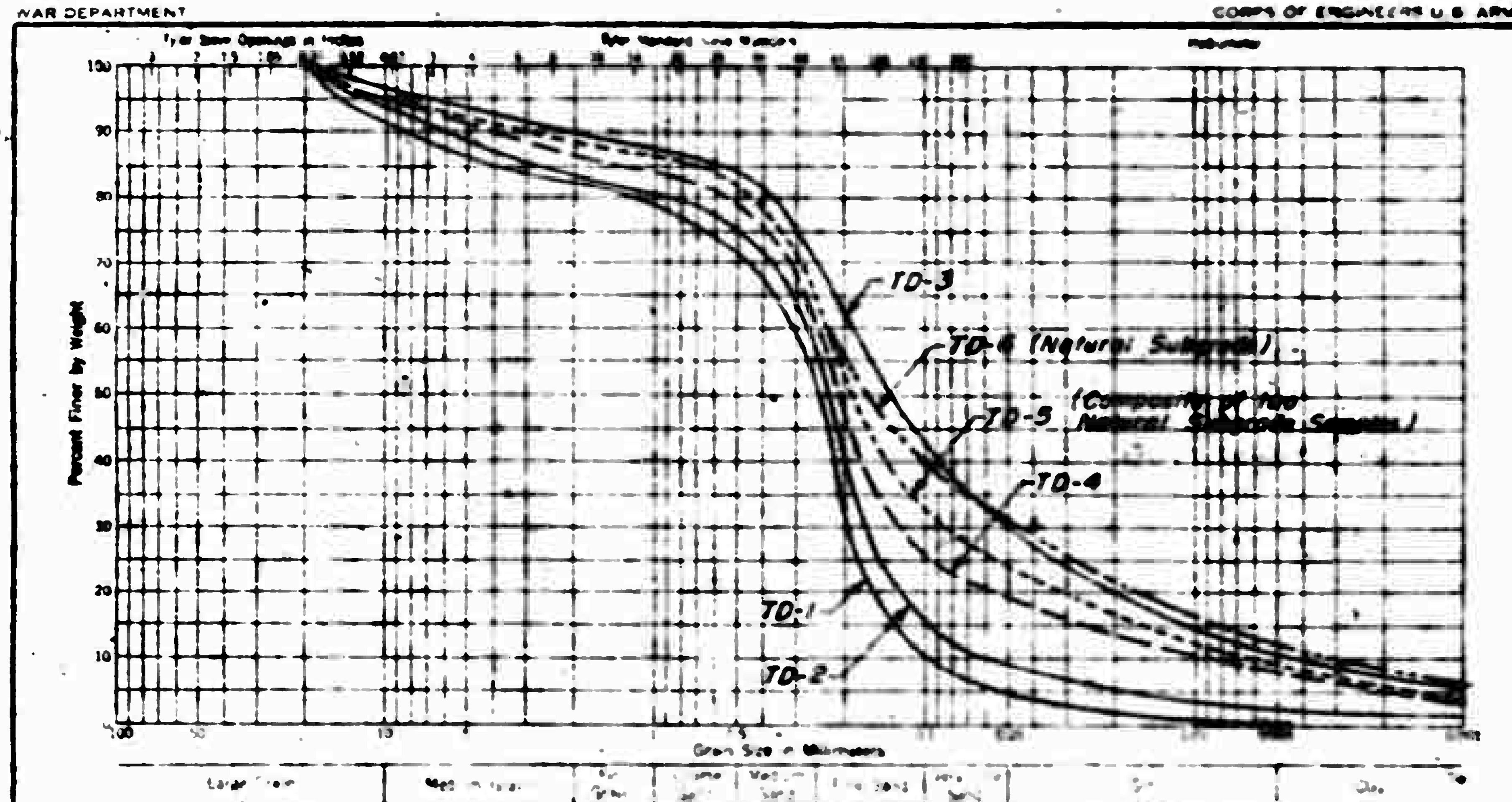
WAR DEPARTMENT

CORPS OF ENGINEERS U. S. ARMY



COLD ROOM STUDIES 1949-1950

GRADATION OF EAST BOSTON TILL, LOWELL SAND,
MANCHESTER FINE SAND AND NEW HAMPSHIRE SILT
AND LIMESTONE SAND AND GRAVEL



COLD ROOM STUDIES 1949-1950

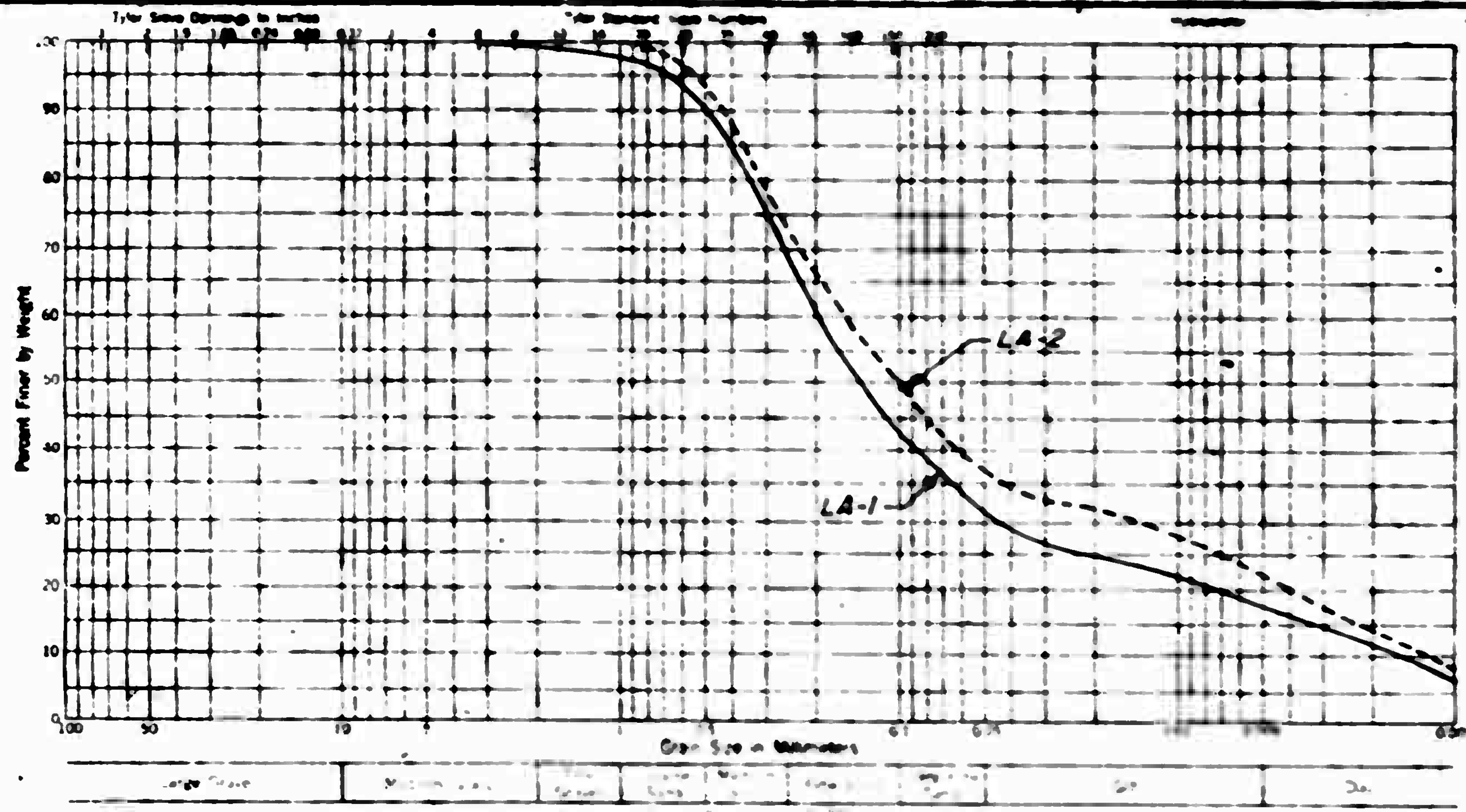
TRUAX FIELD BASE AND SUB-BASE MATERIAL, MADISON, WISCONSIN

NOTE:

SAMPLES TD-1, TD-2, TD-3 AND TD-4 HAVE BEEN REGRADED FROM GRADED AGGREGATE. TD-5 AND TD-6 ARE NATURAL MATERIALS WITH AGGREGATE LARGER THAN 3/4" REMOVED PRIOR TO TESTING.

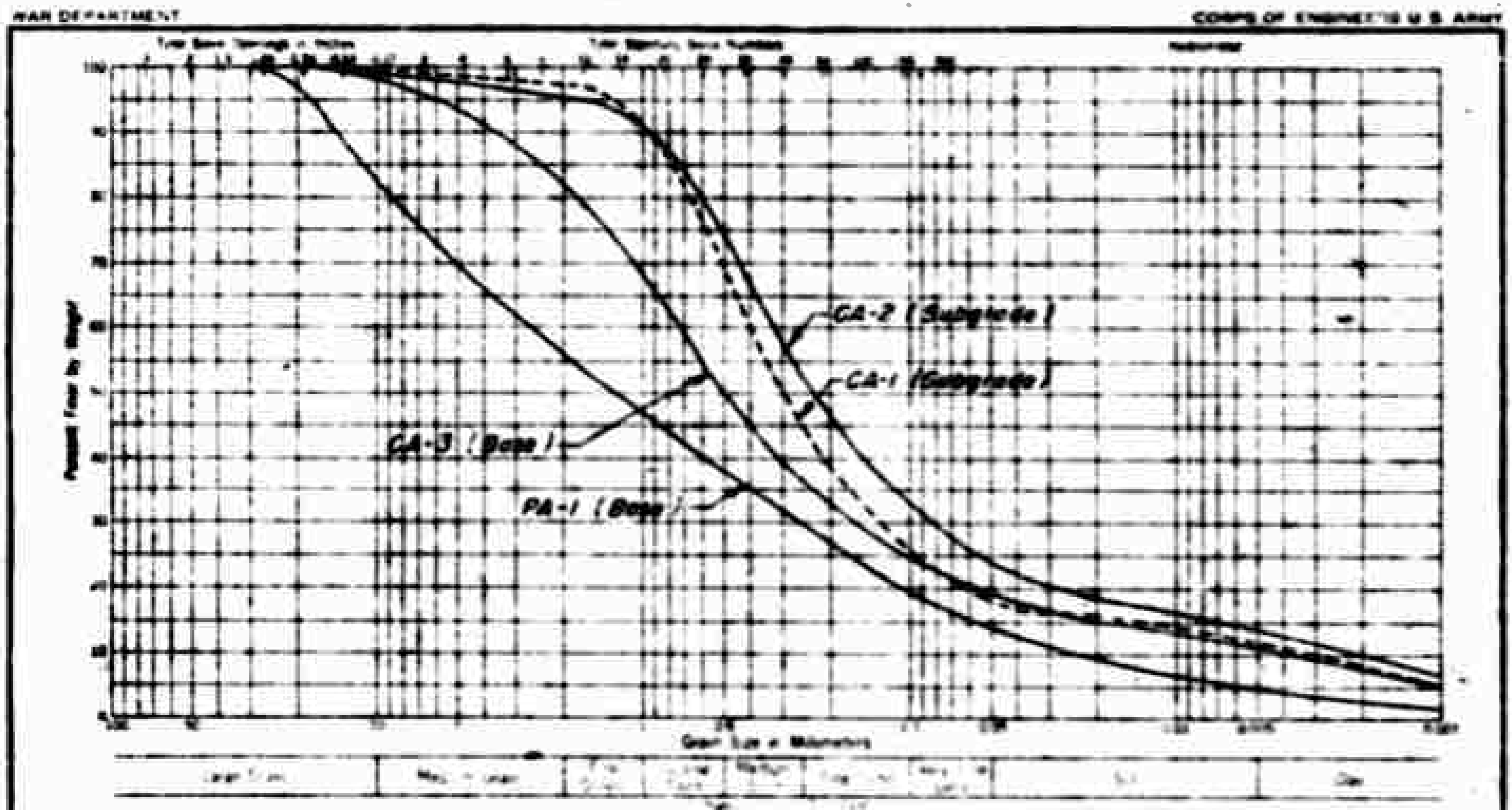
WAR DEPARTMENT

CORPS OF ENGINEERS U.S. ARMY



COLD ROOM STUDIES 1949-1950

SUBGRADE SOILS FROM LOWRY AIRFIELD, DENVER, COLORADO

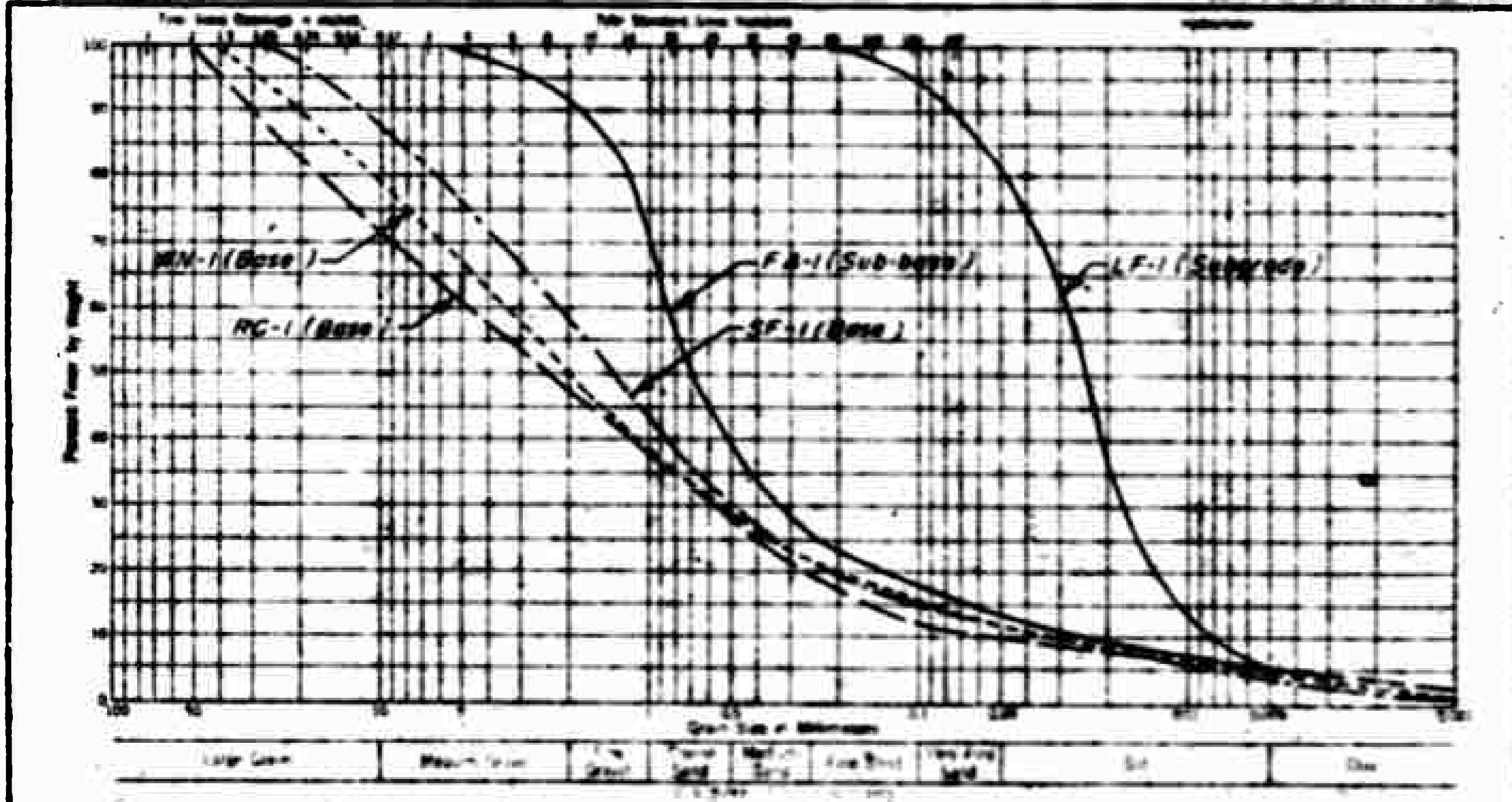


COLD ROOM STUDIES 1949-1950

BASE AND SUBGRADE SOILS FROM PIERRE AIRFIELD, SOUTH DAKOTA
AND CASPER AIRBASE, WYOMING

WAR DEPARTMENT

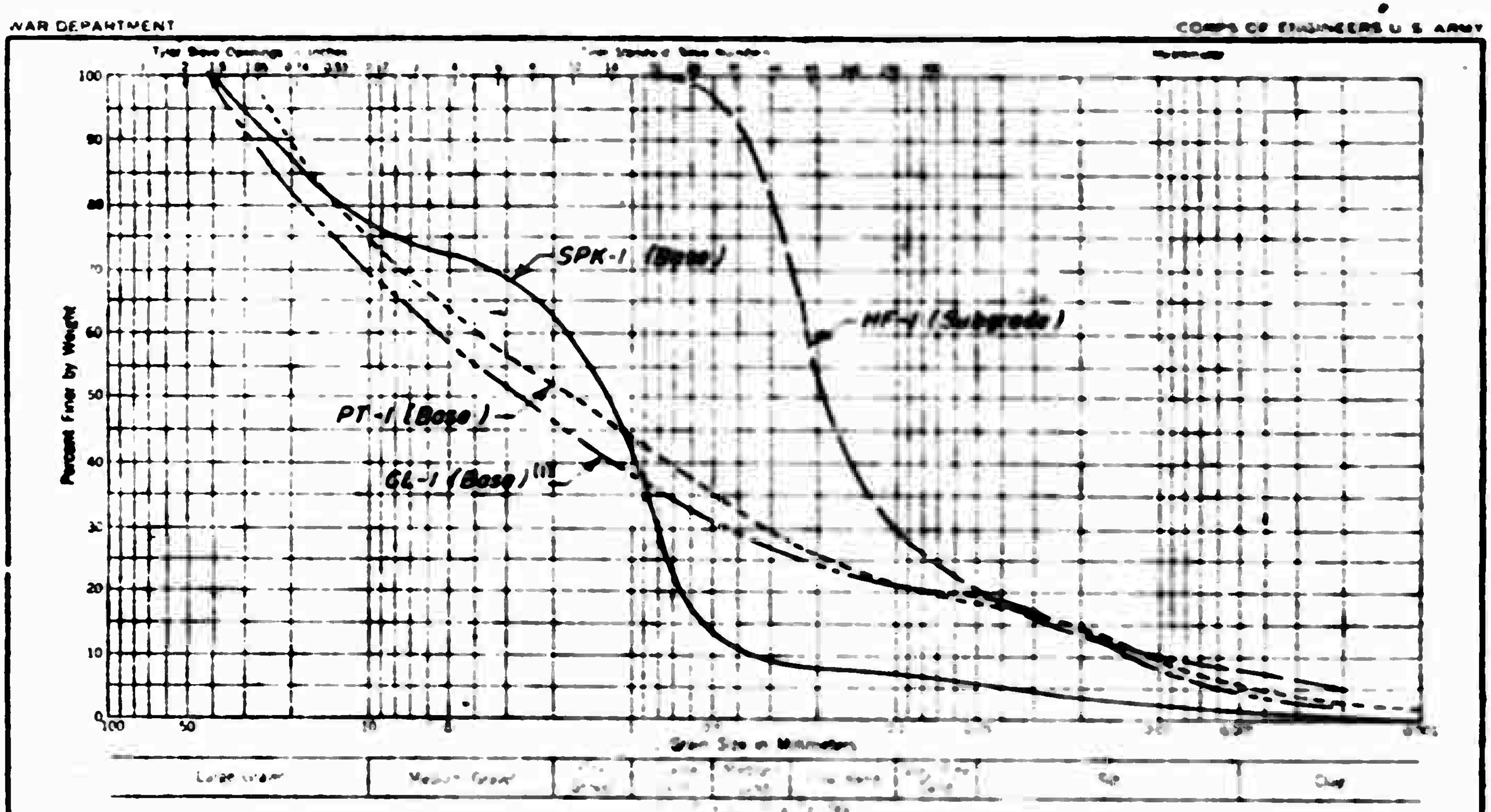
CORPS OF ENGINEERS U.S. ARMY



COLD ROOM STUDIES 1949-1950

FARGO SUB-BASE, WENDOVER, SIOUX FALLS AND RAPID CITY BASE MATERIALS AND LADD FIELD, ALASKA, SUBGRADE SOIL

PLATE 14

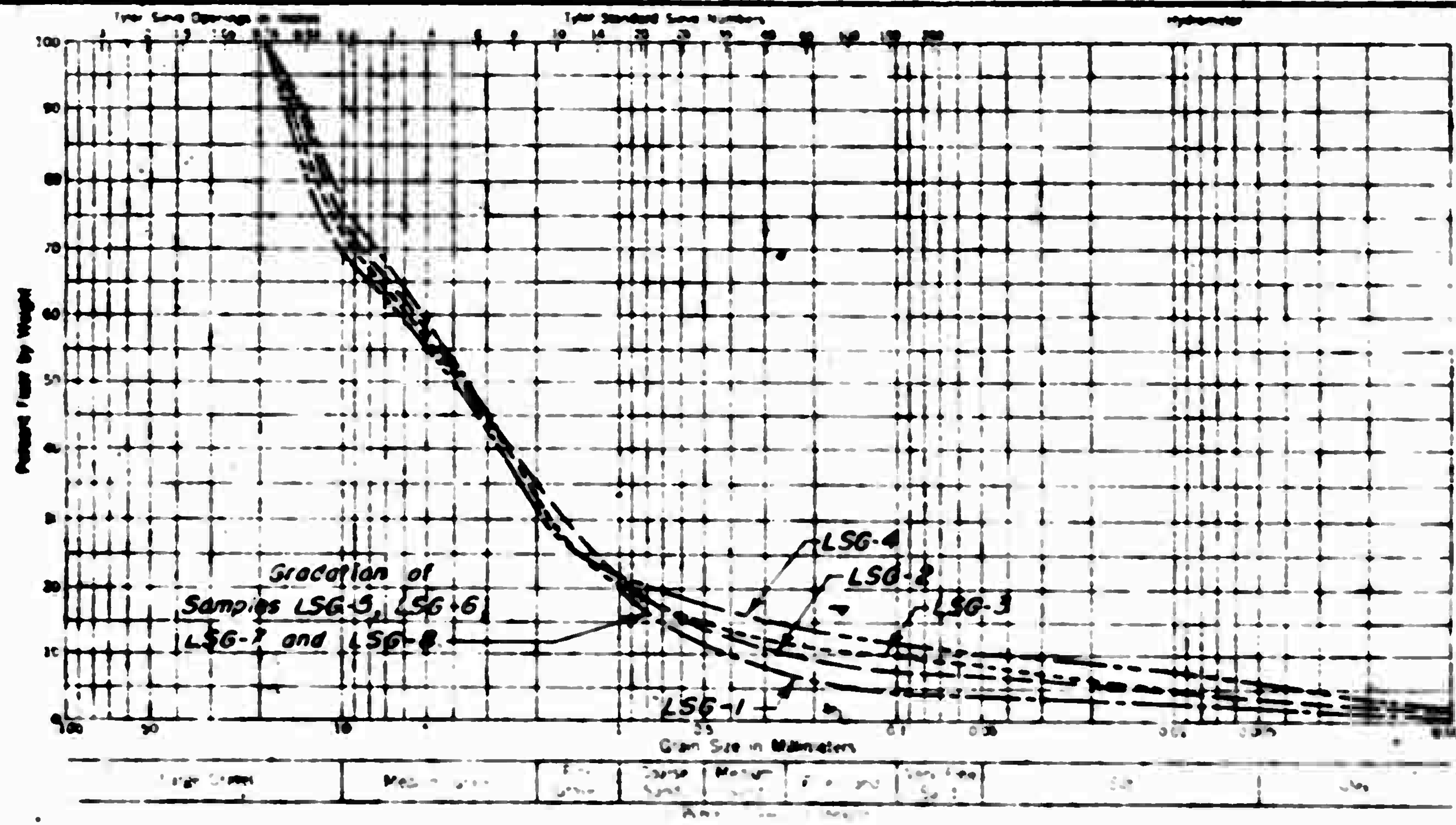


COLD ROOM STUDIES 1949-1950

BASE OR SUBGRADE SOILS FROM CLINTON COUNTY AIRFIELD, WILMINGTON, OHIO; SPOKANE AIRFIELD, WASHINGTON; PATTERSON FIELD, FAIRFIELD, OHIO AND HILL FIELD, OGDEN, UTAH

(1) LARGER SIZE AGGREGATE REMOVED FROM SAMPLE BEFORE TESTING

WAR DEPARTMENT CORPS OF ENGINEERS U. S. ARMY

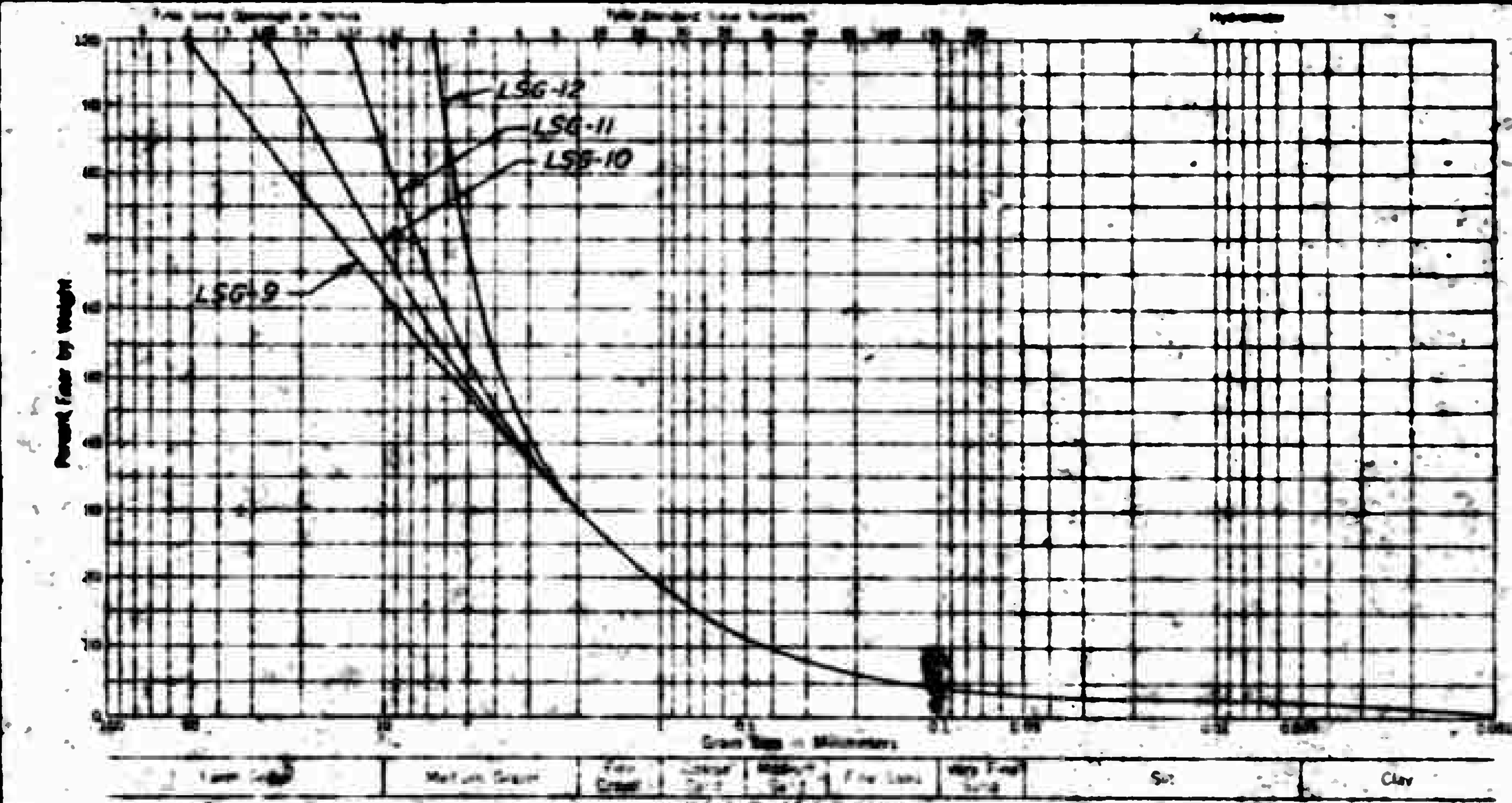


COLD ROOM STUDIES 1949-1950

LIMESTONE, MAINE SAND AND GRAVEL
(Gradation reconstructed from graded aggregate)

WAR DEPARTMENT

CORPS OF ENGINEERS U. S. ARMY

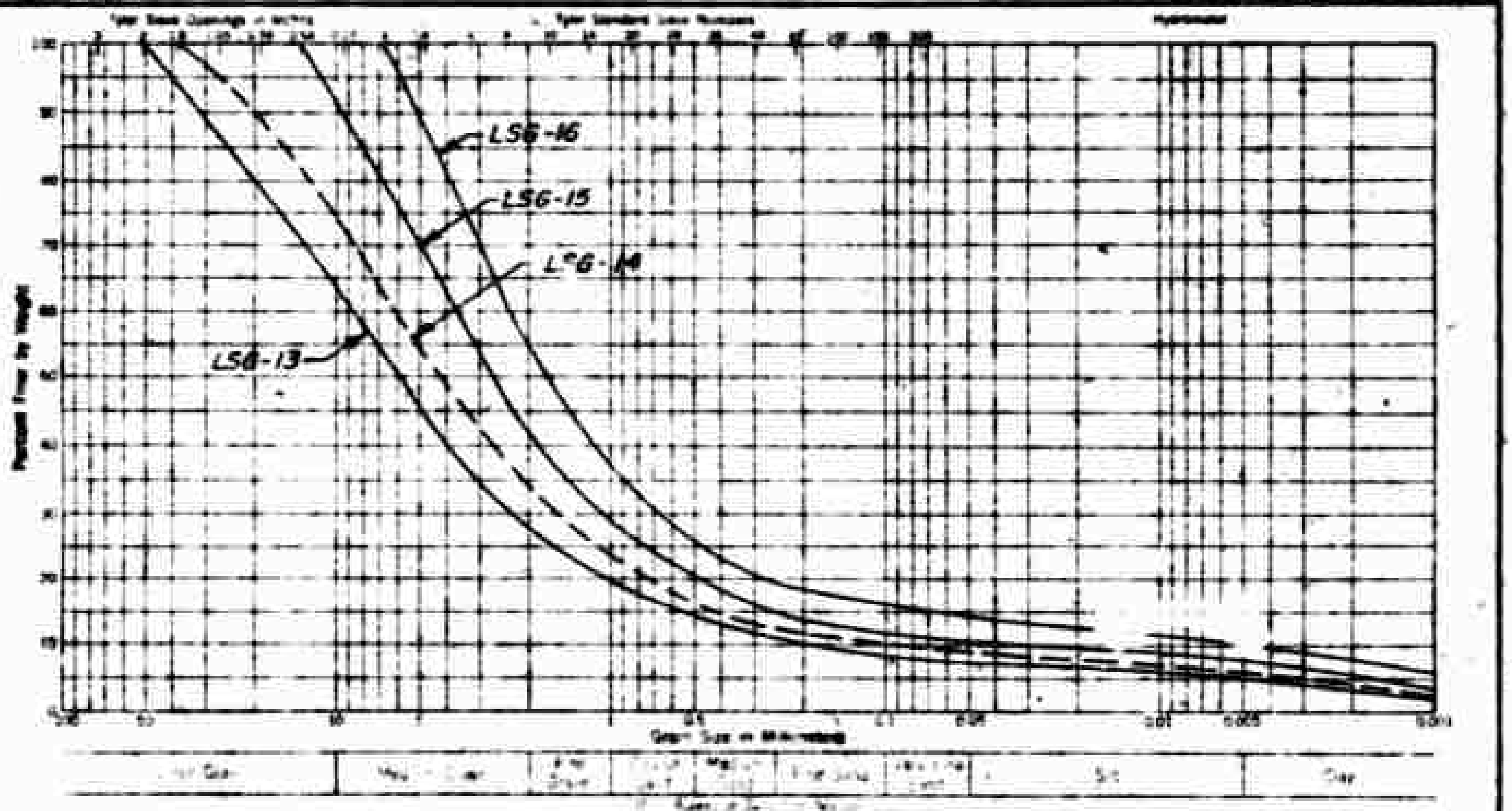


COLD ROOM STUDIES 1949-1950

LIMESTONE SAND AND GRAVEL

WAR DEPARTMENT

CORPS OF ENGINEERS U. S. ARMY

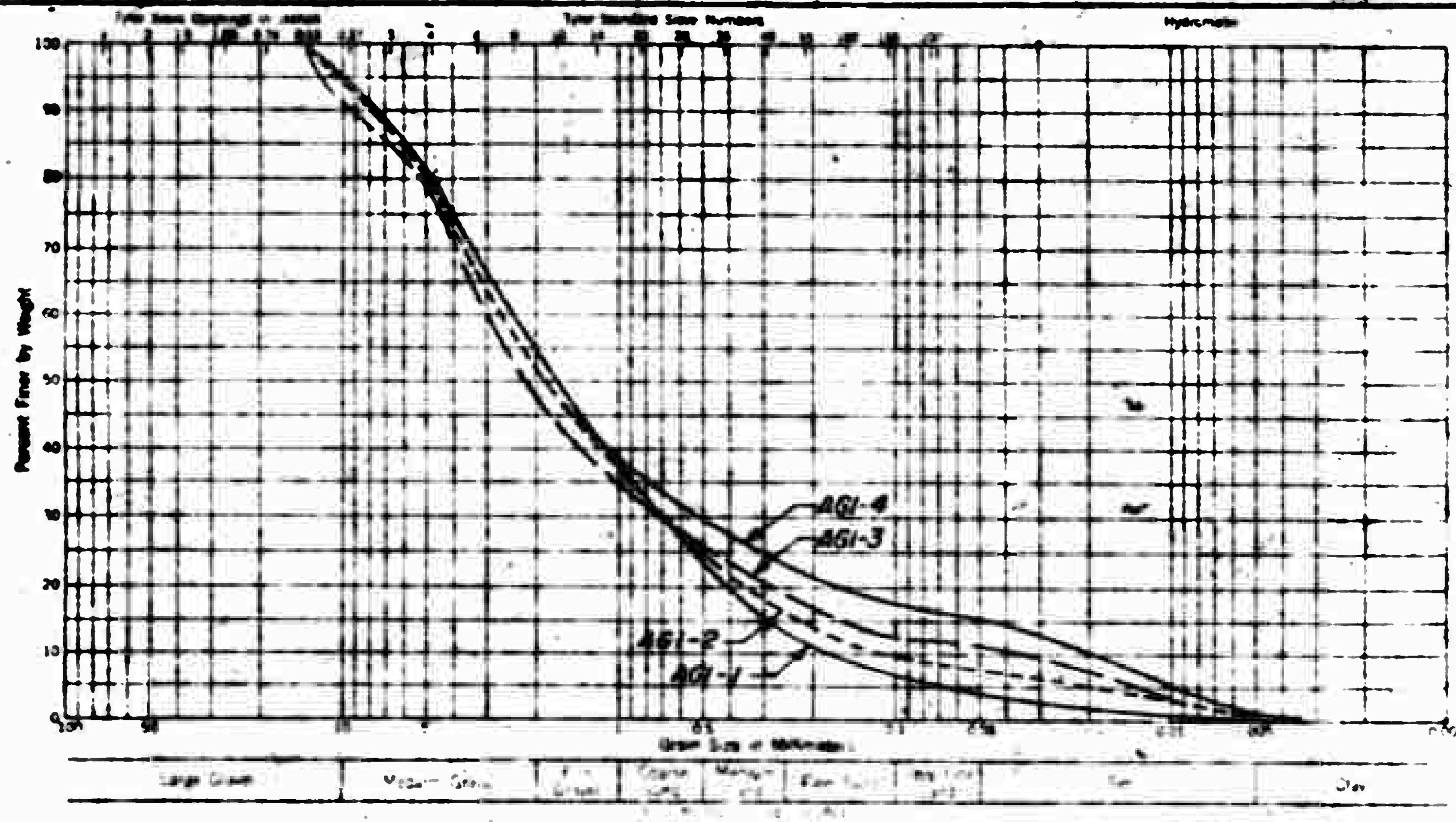


COLD ROOM STUDIES 1949-1950

LIMESTONE SAND AND GRAVEL
(NATURAL MATERIAL)

WAR DEPARTMENT

CORPS OF ENGINEERS U.S. ARMY

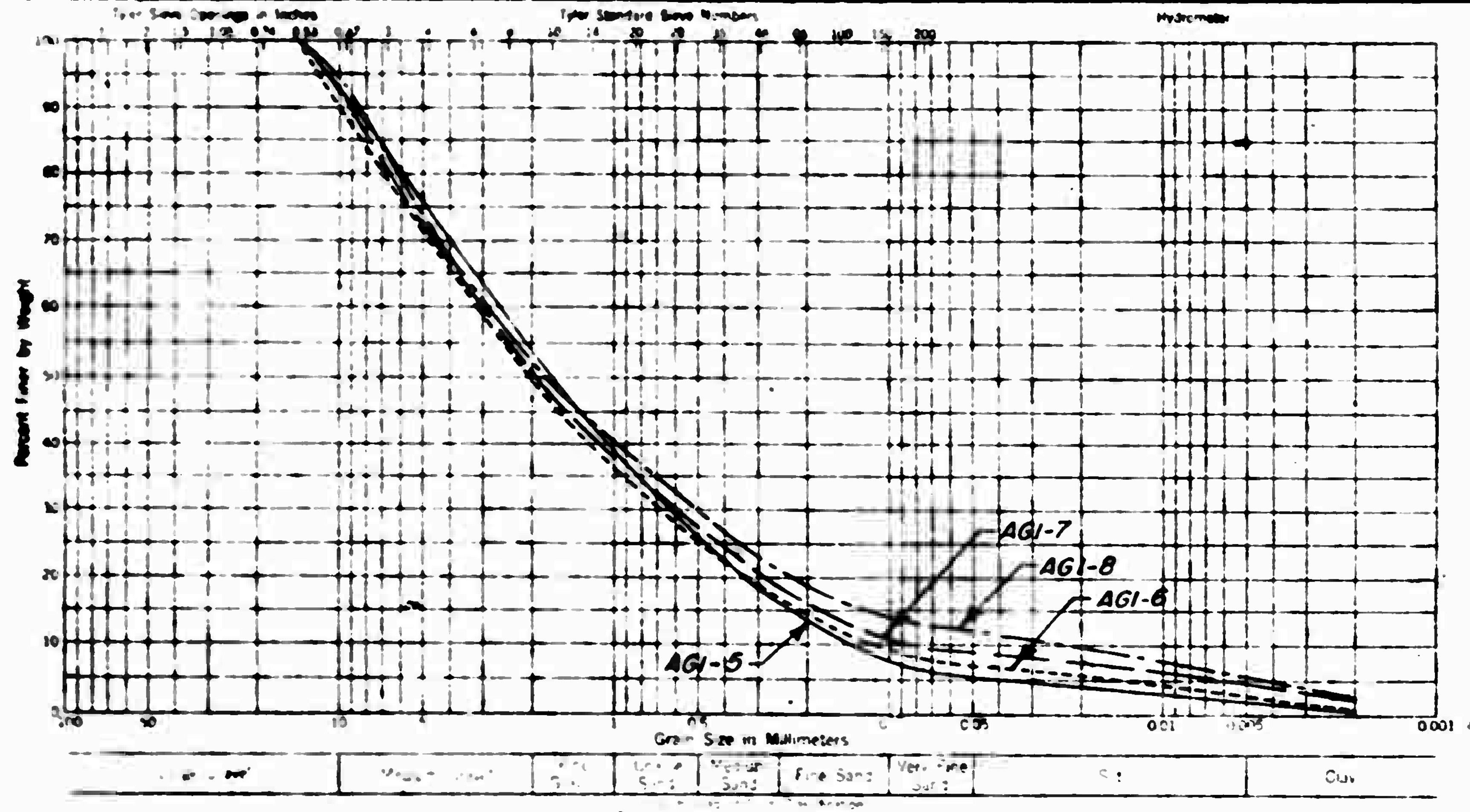


COLD ROOM STUDIES 1949-1950

PEABODY, MASS. SAND AND GRAVEL BLENDED WITH NEW HAMPSHIRE SILT

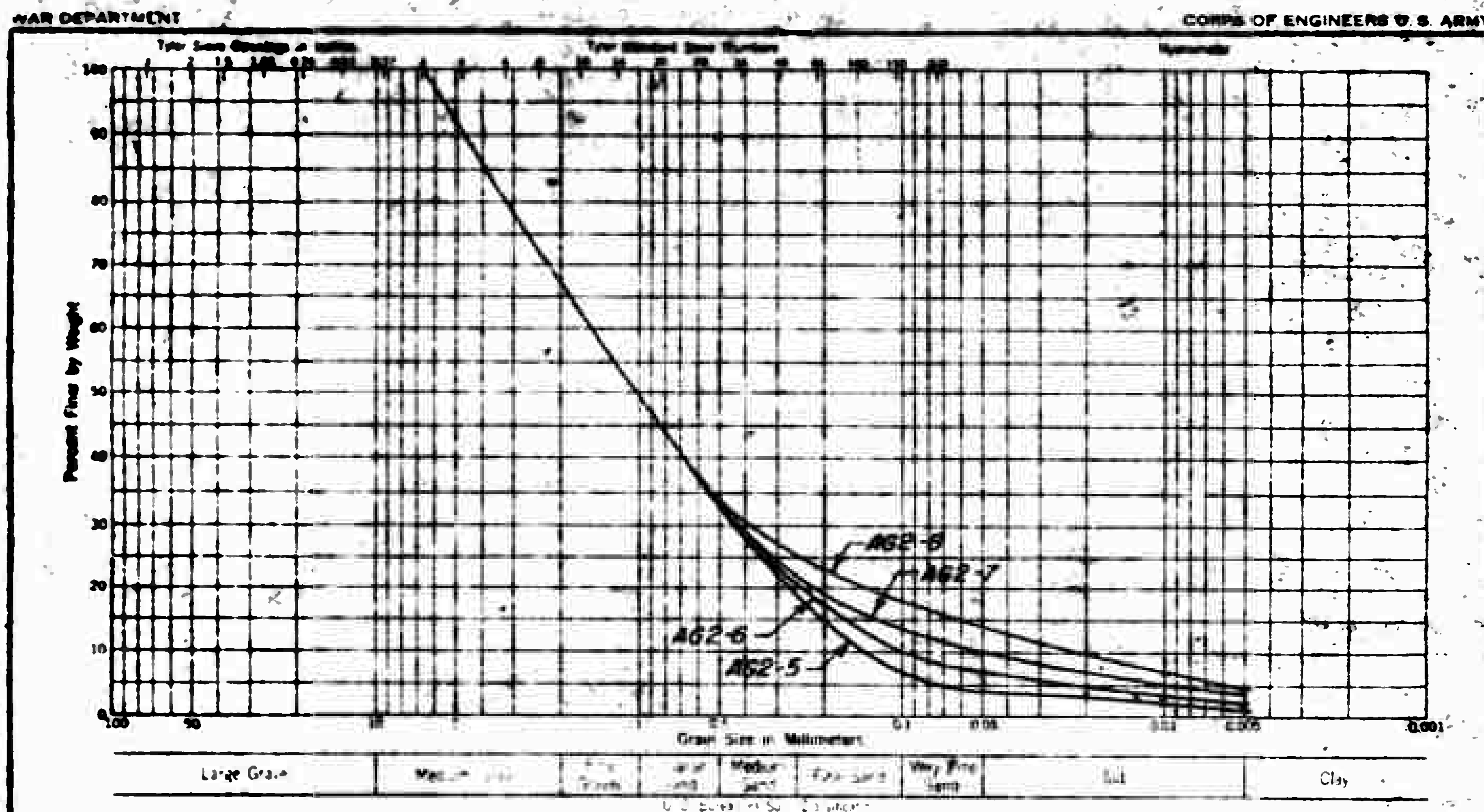
WAR DEPARTMENT

CORPS OF ENGINEERS U. S. ARMY



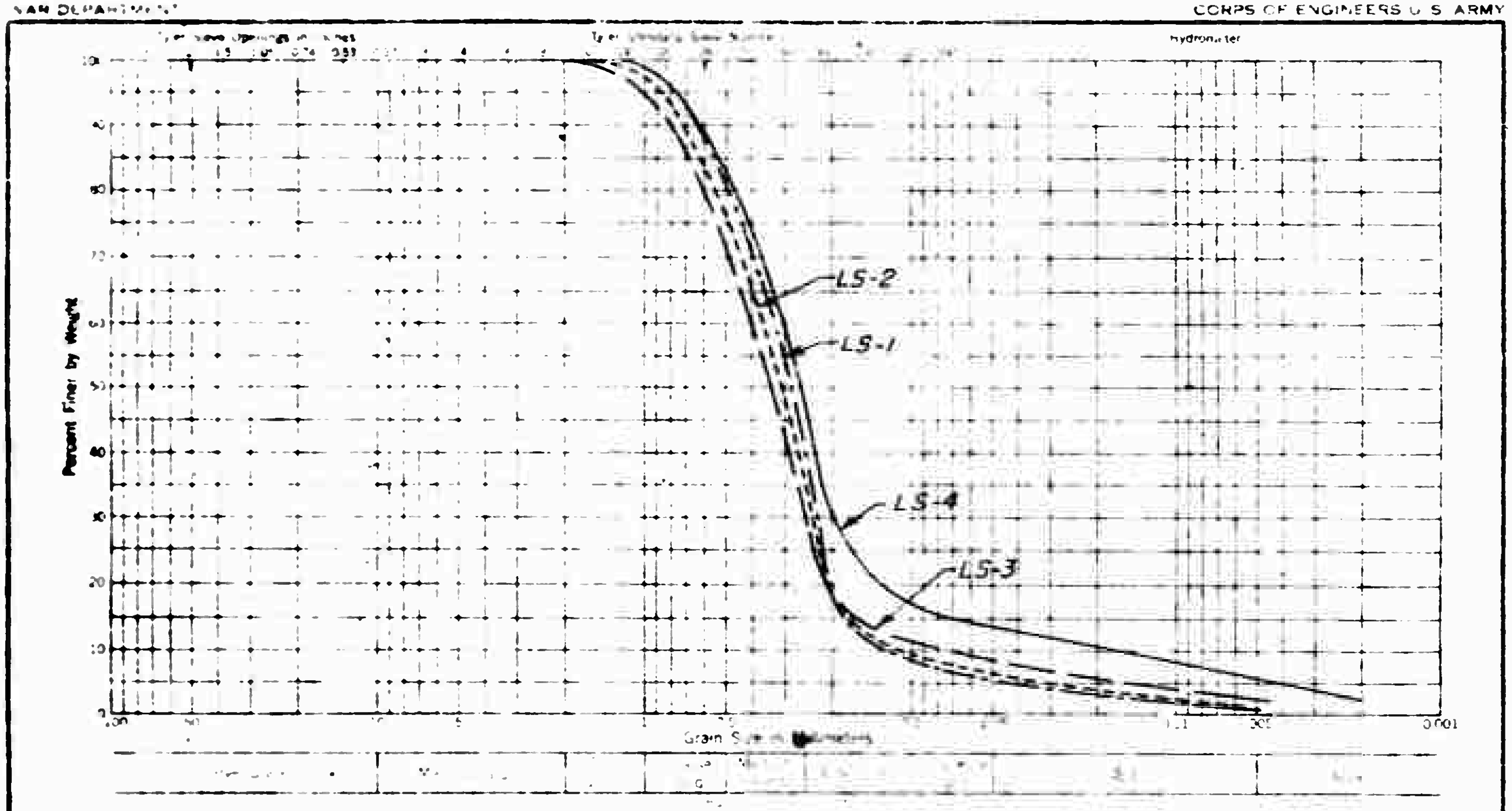
COLD ROOM STUDIES 1949-1950

PEABODY, MASS. SAND AND GRAVEL BLENDED WITH EAST BOSTON TILL



COLD ROOM STUDIES 1949-1950

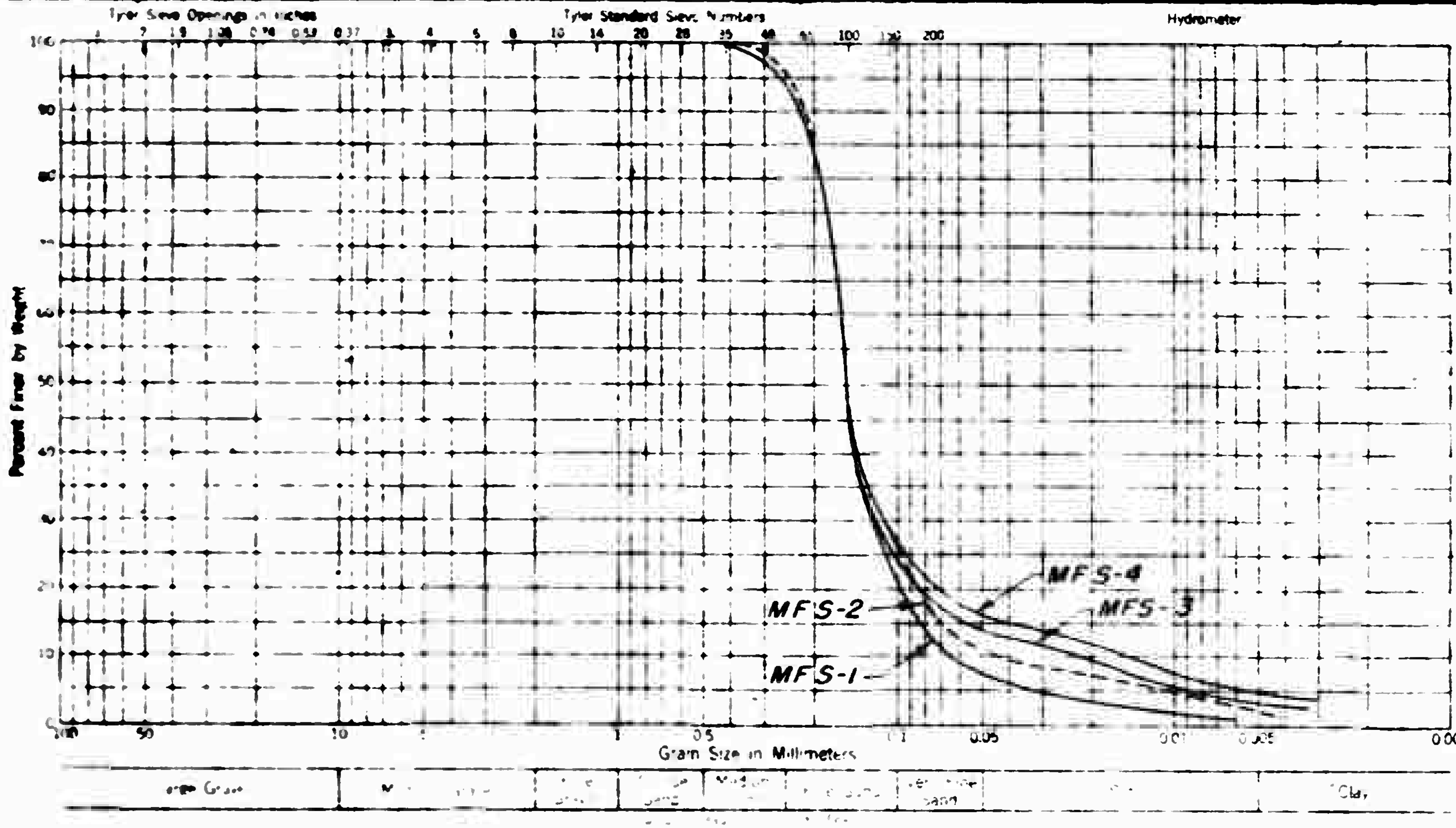
PEABODY, MASS. SAND AND GRAVEL BLENDED WITH NEW HAMPSHIRE SILT



COLD ROOM STUDIES 1949-1950

LOWELL SAND BLENDED WITH EAST BOSTON TILL

WAR DEPARTMENT CORPS OF ENGINEERS U S ARMY

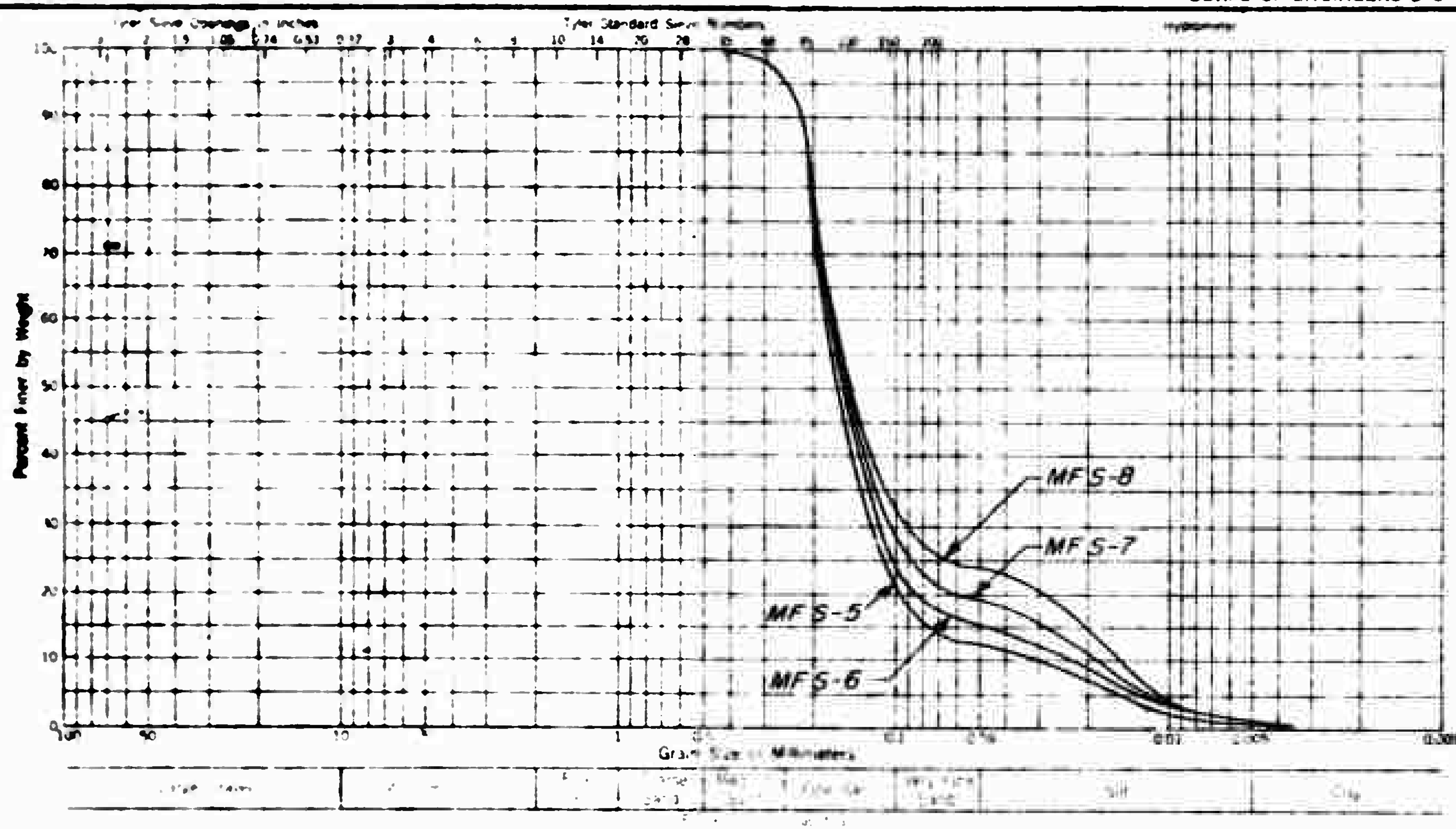


COLD ROOM STUDIES 1949-1950

MANCHESTER FINE SAND BLENDED WITH EAST BOSTON TILL

WAR DEPARTMENT

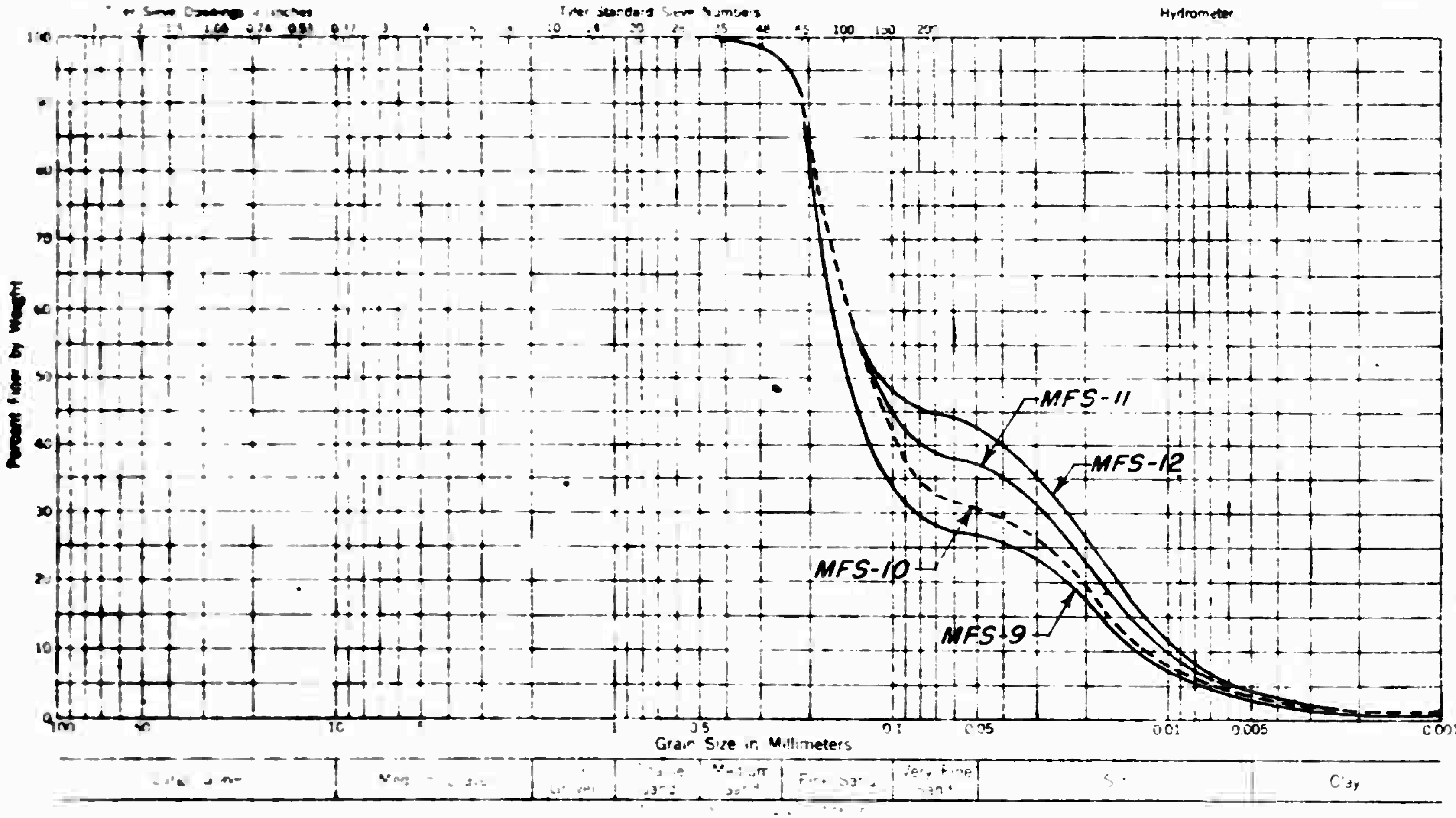
CORPS OF ENGINEERS U S ARMY



COLD ROOM STUDIES 1949-1950

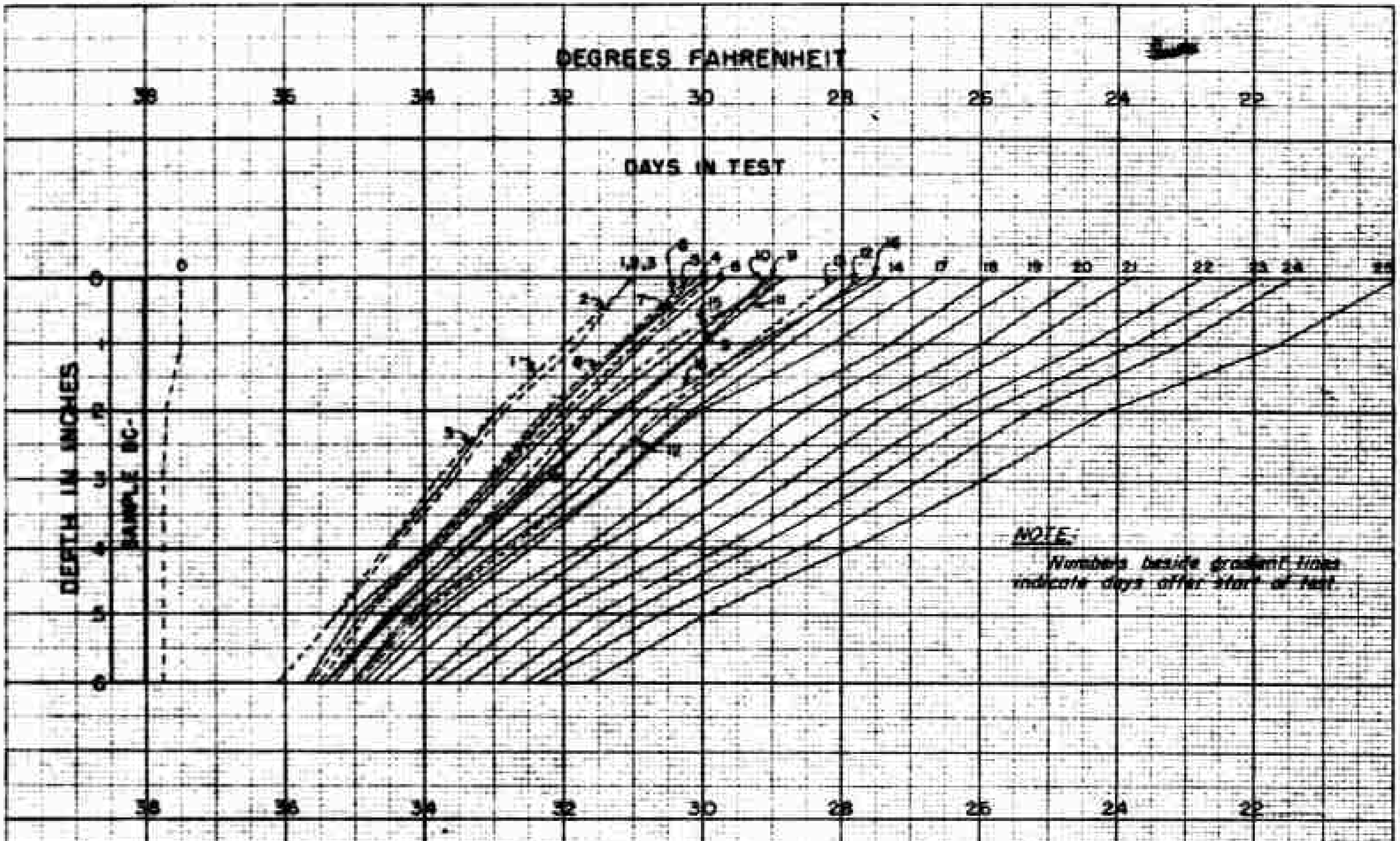
MANCHESTER FINE SAND BLENDED WITH NEW HAMPSHIRE SILT

WAR DEPARTMENT CORPS OF ENGINEERS U S ARMY



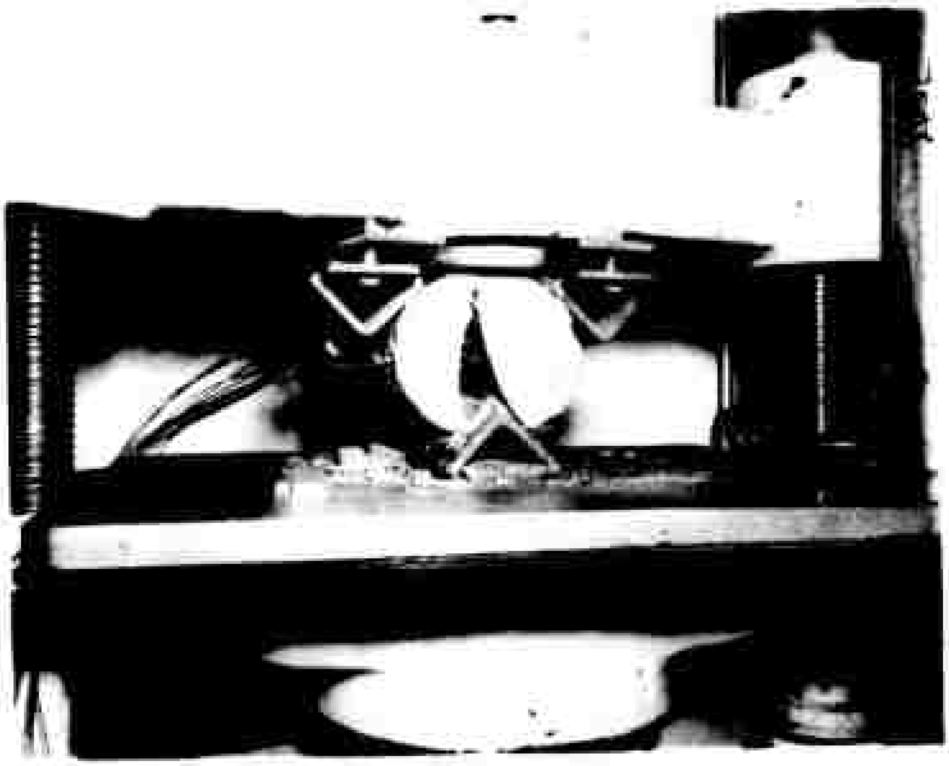
COLD ROOM STUDIES 1949-1950

MANCHESTER FINE SAND BLENDED WITH NEW HAMPSHIRE SILT

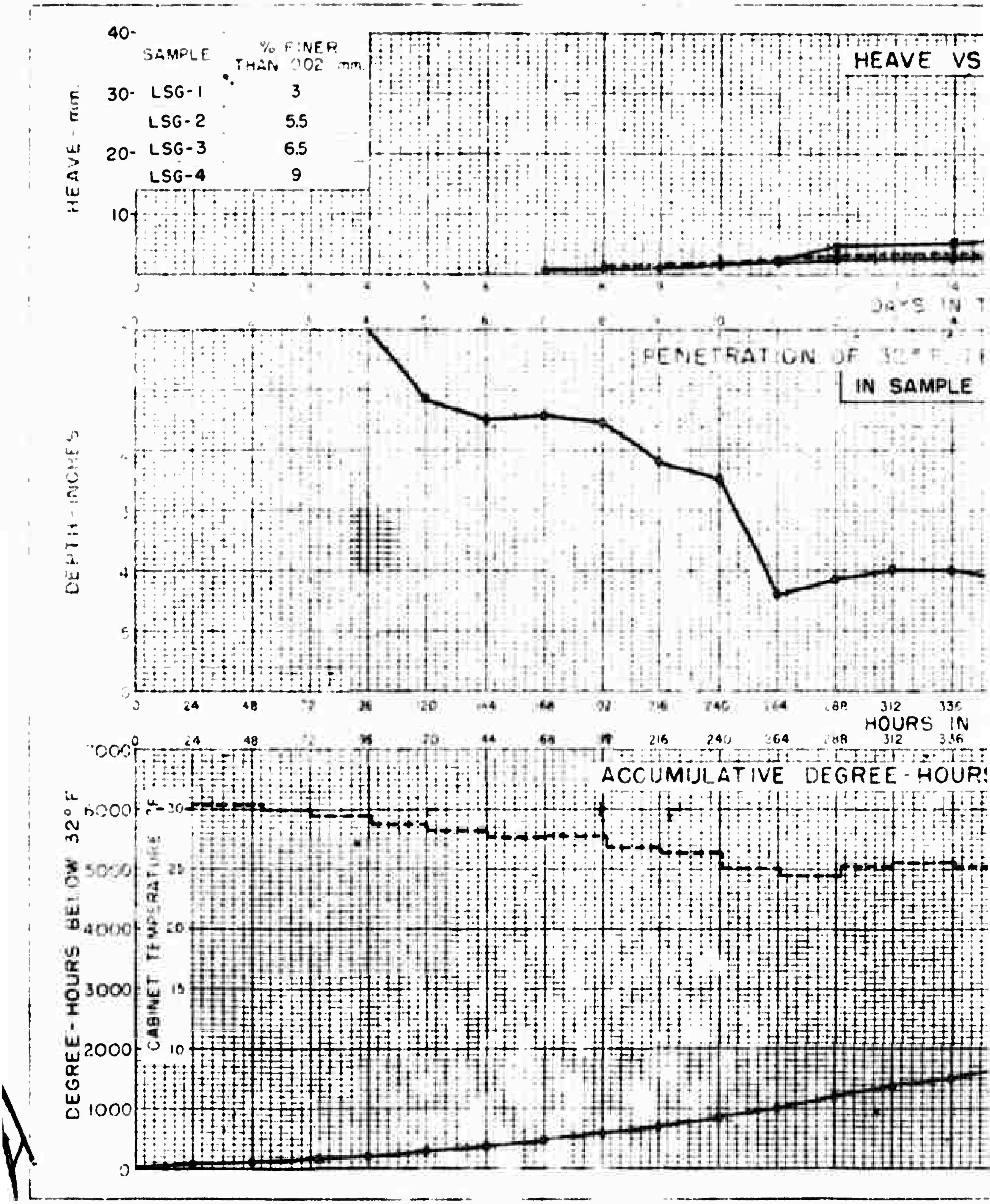


COLD ROOM STUDIES 1949-1950

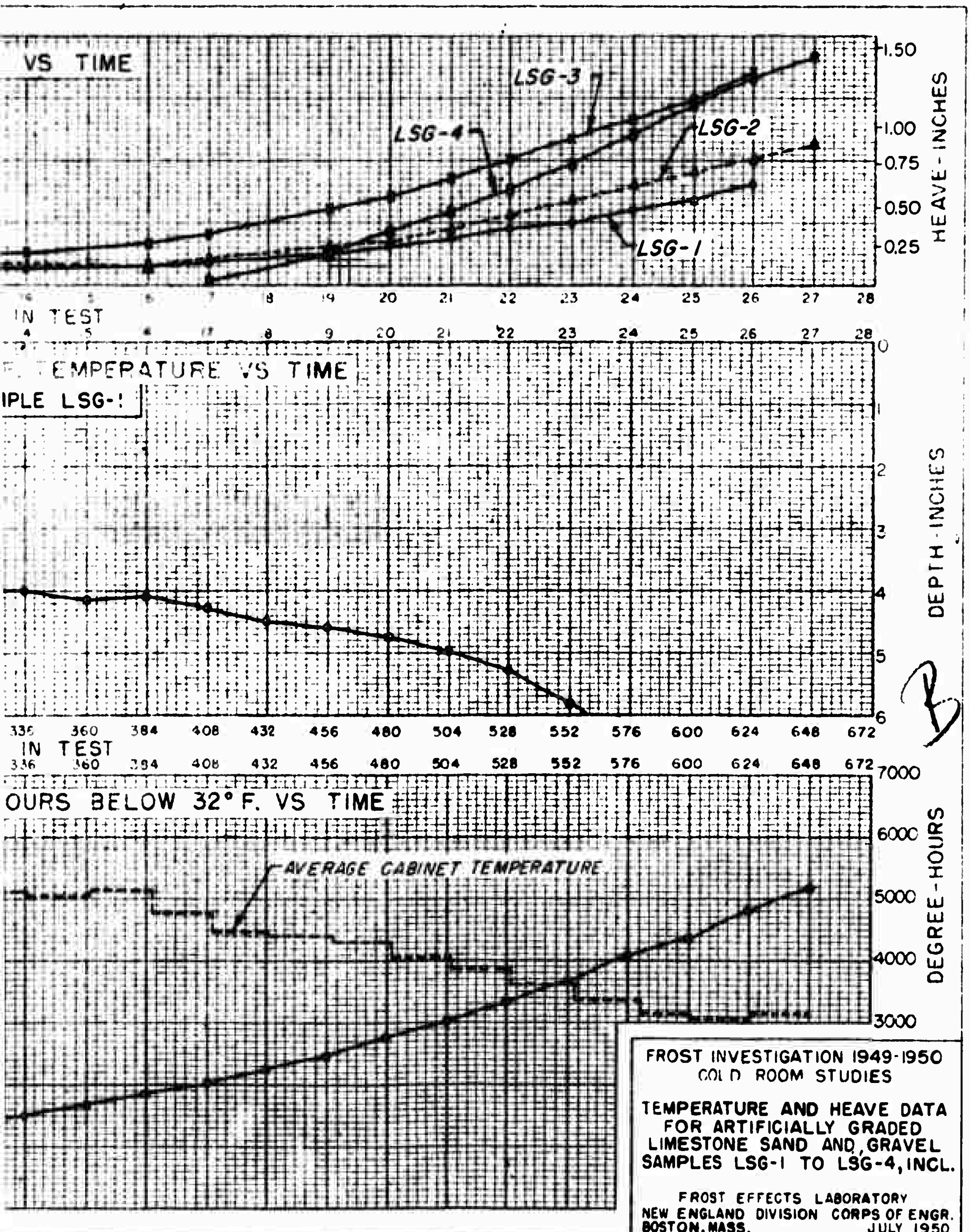
TYPICAL DAILY TEMPERATURE GRADIENTS IN SOIL SPECIMENS



PHOTOGRAPH OF SOIL SPECIMEN BEING SPLIT ON THE COMPRESSION MACHINE. NOTE THERMOCOUPLE WIRES IN PLACE.



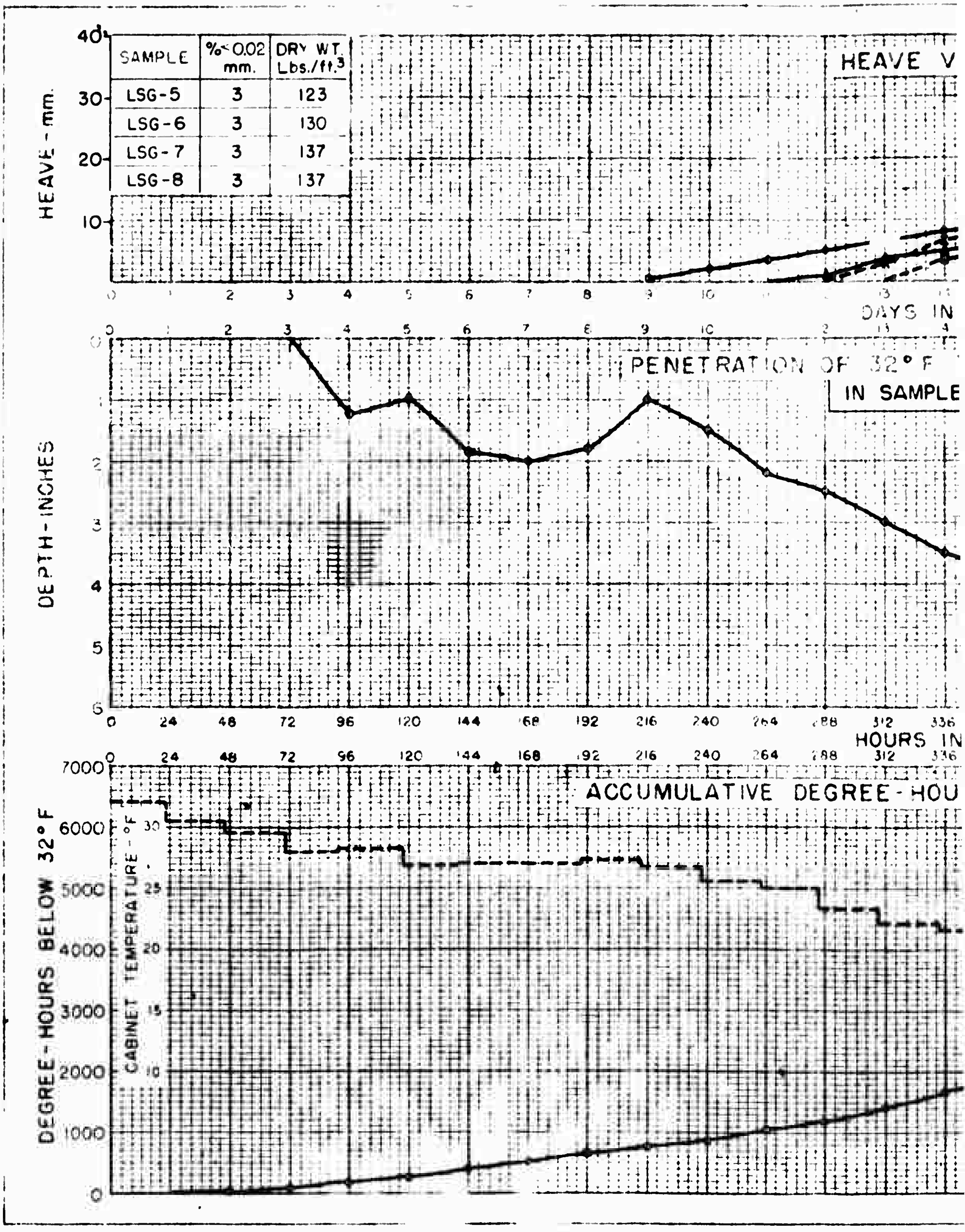
SAMPLE
% FINER THAN .002 mm.
LSG-1 3
LSG-2 5.5
LSG-3 6.5
LSG-4 9
HEAVE - mm.
HEAVE VS
DAYS IN T
PENETRATION OF
IN SAMPLE
DEPTH - INCHES
HOURS IN
ACCUMULATIVE DEGREE-HOURS
DEGREE-HOURS BELOW 32° F
CABINET TEMPERATURE °F



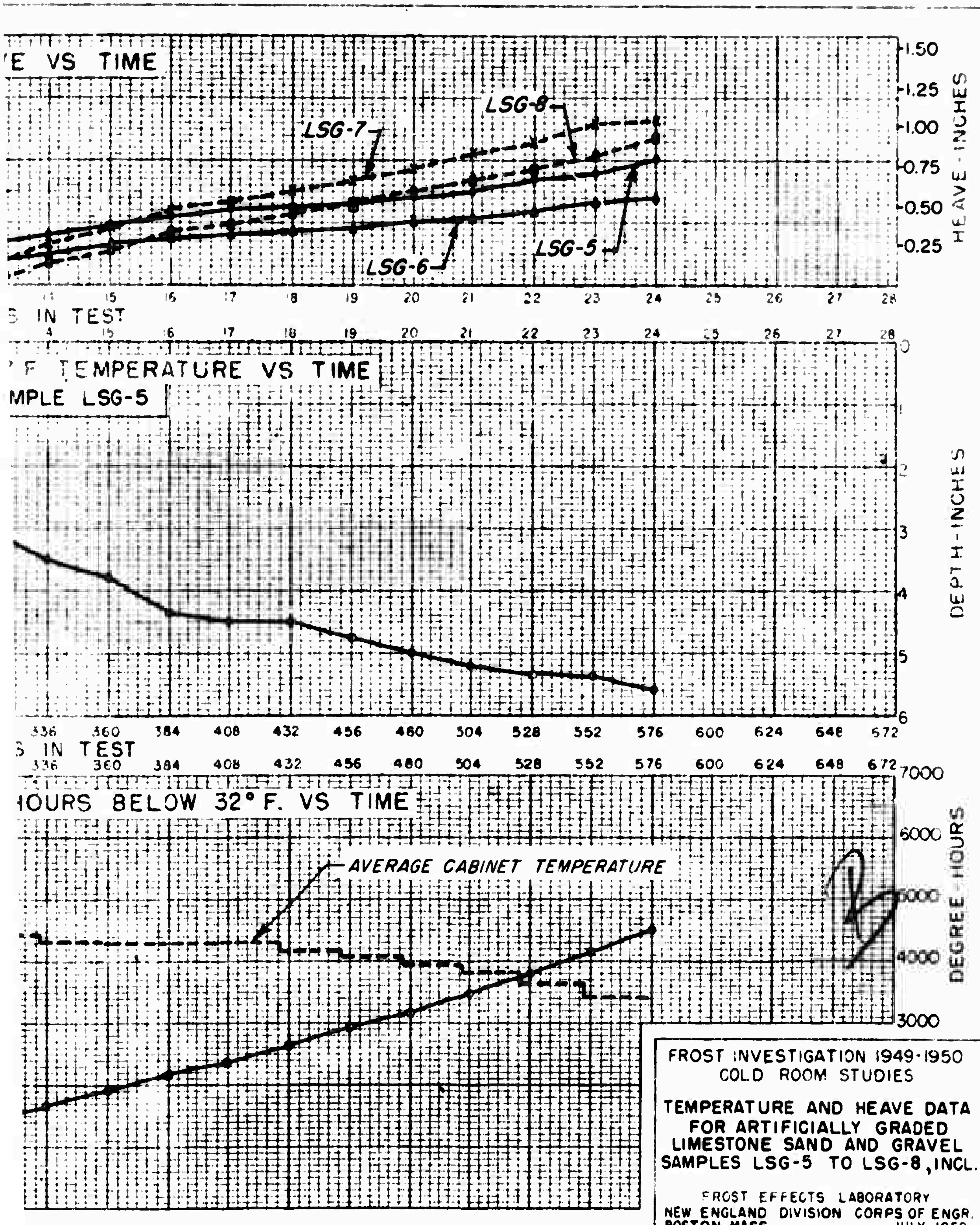
FROST INVESTIGATION 1949-1950
COLD ROOM STUDIES

TEMPERATURE AND HEAVE DATA FOR ARTIFICIALLY GRADED LIMESTONE SAND AND GRAVEL SAMPLES LSG-1 TO LSG-4, INCL.

FROST EFFECTS LABORATORY
NEW ENGLAND DIVISION CORPS OF ENGR.
BOSTON, MASS. JULY 1950



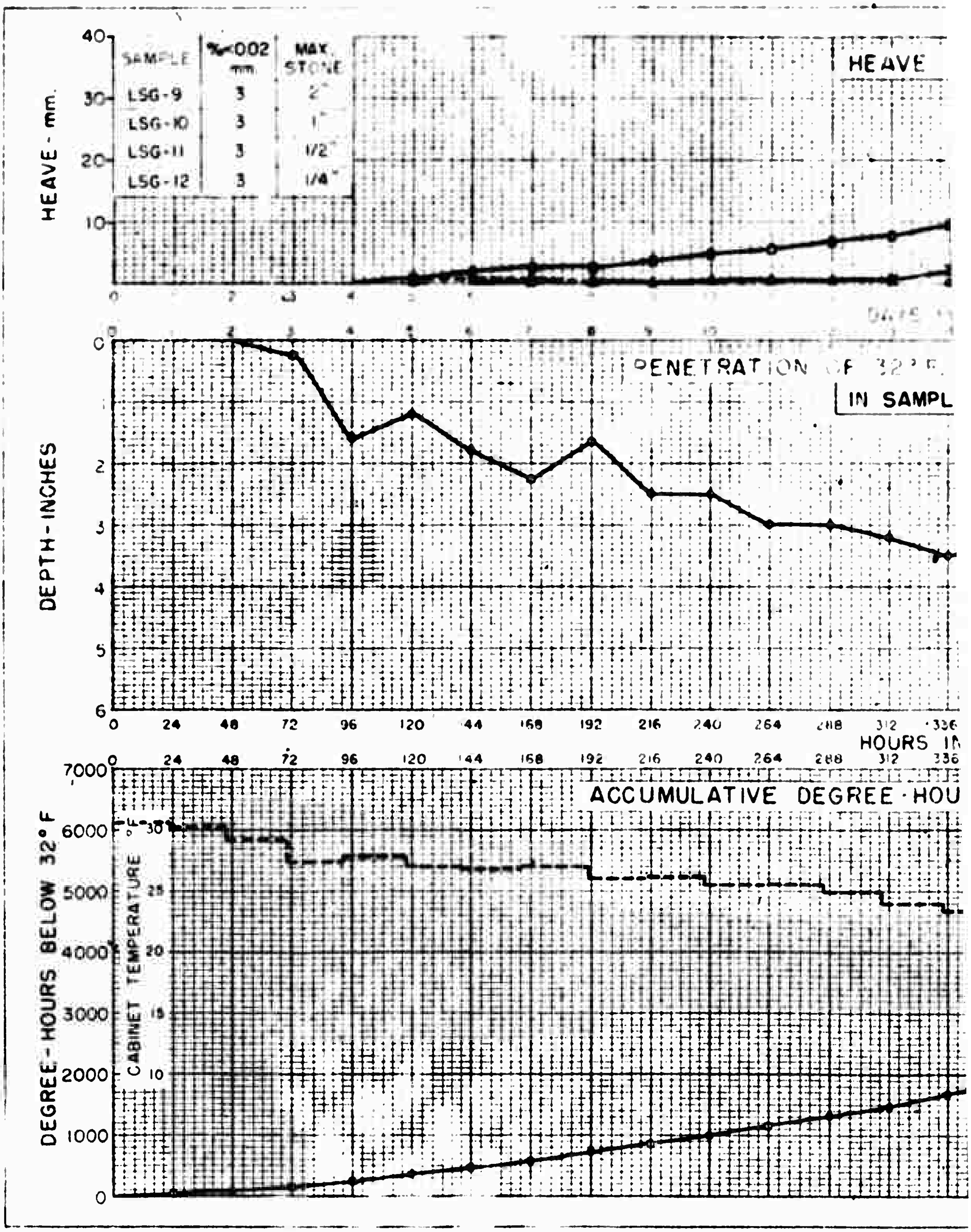
SAMPLE	%< 0.02 mm.	DRY WT. Lbs./ft.^{3}
LSG-5	3	123
LSG-6	3	130
LSG-7	3	137
LSG-8	3	137

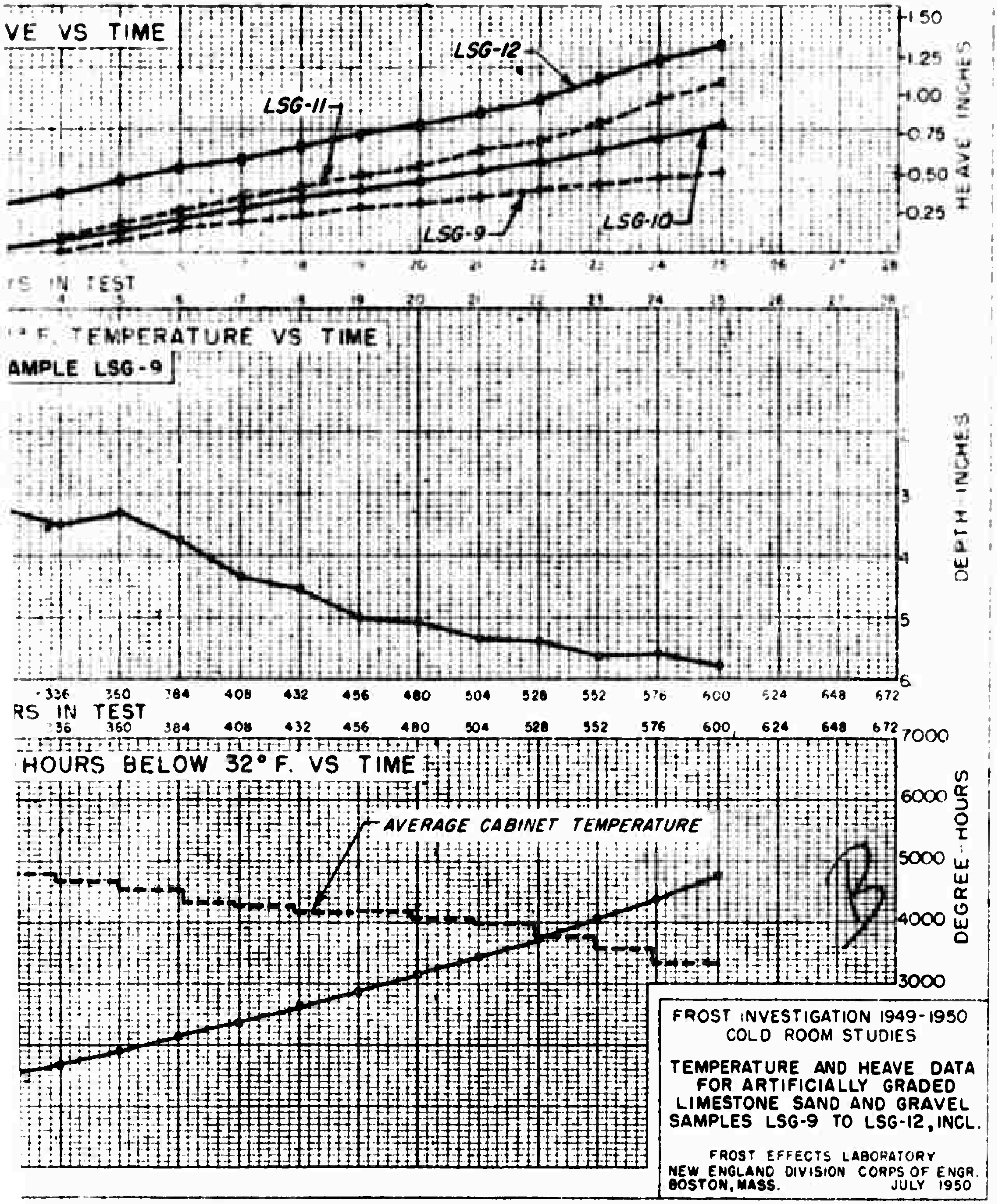


FROST INVESTIGATION 1949-1950
COLD ROOM STUDIES

TEMPERATURE AND HEAVE DATA FOR ARTIFICIALLY GRADED LIMESTONE SAND AND GRAVEL SAMPLES LSG-5 TO LSG-8, INCL.

FROST EFFECTS LABORATORY
NEW ENGLAND DIVISION CORPS OF ENGR.
BOSTON, MASS. JULY 1950


HEAVE
HEAVE - mm.
SAMPLE
% <.002 mm
MAX. STONE
LSG-9 3 2"
LSG-10 3 1"
LSG-11 3 1/2"
LSG-12 3 1/4"
PENETRATION OF 32° F
IN SAMPL
DEPTH - INCHES
HOURS IN
ACCUMULATIVE DEGREE · HOU
DEGREE - HOURS BELOW 32° F
CABINET TEMPERATURE °F
0 24 48 72 96 120 144 168 192 216 240 264 288 312 336

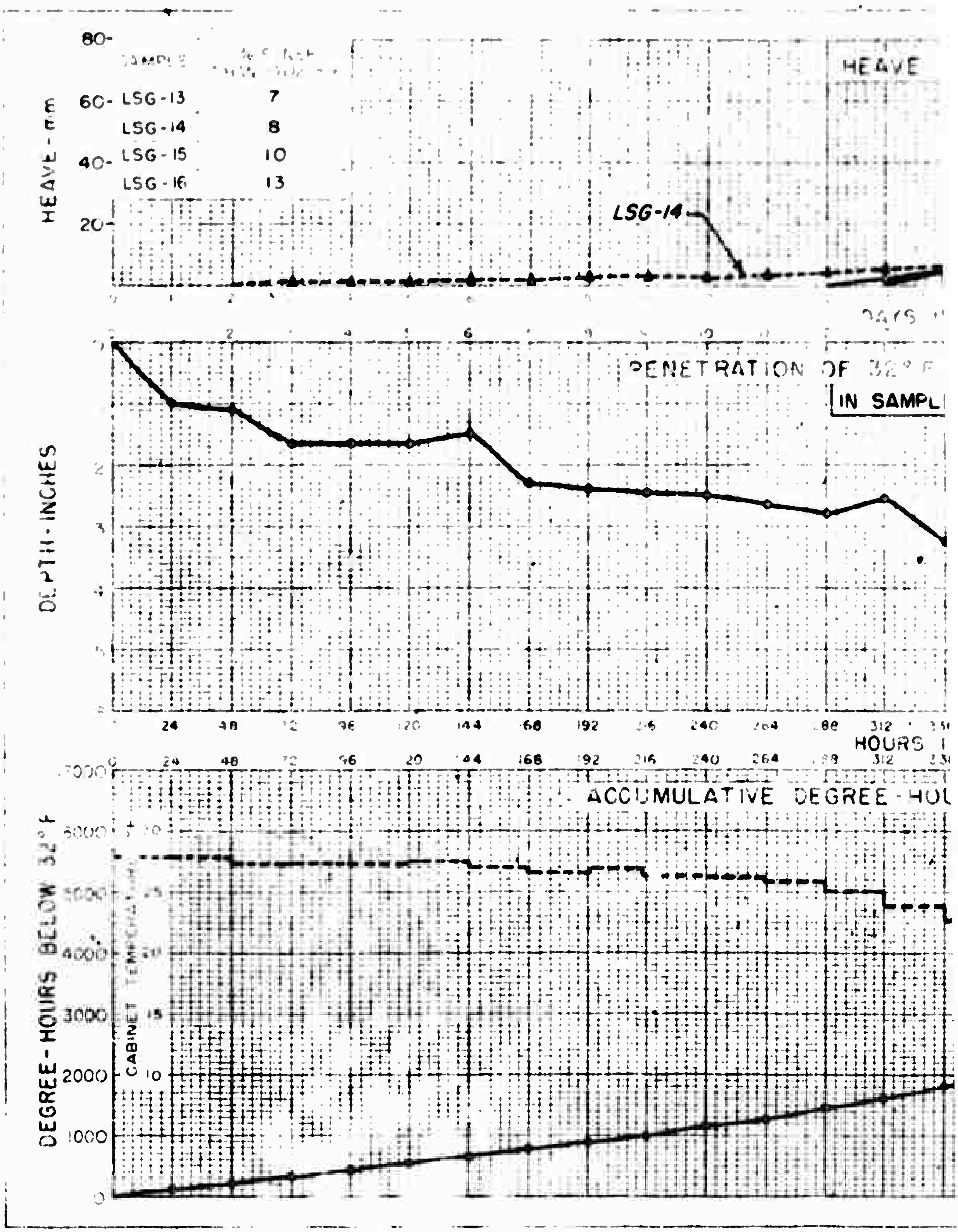


FROST INVESTIGATION 1949-1950
COLD ROOM STUDIES

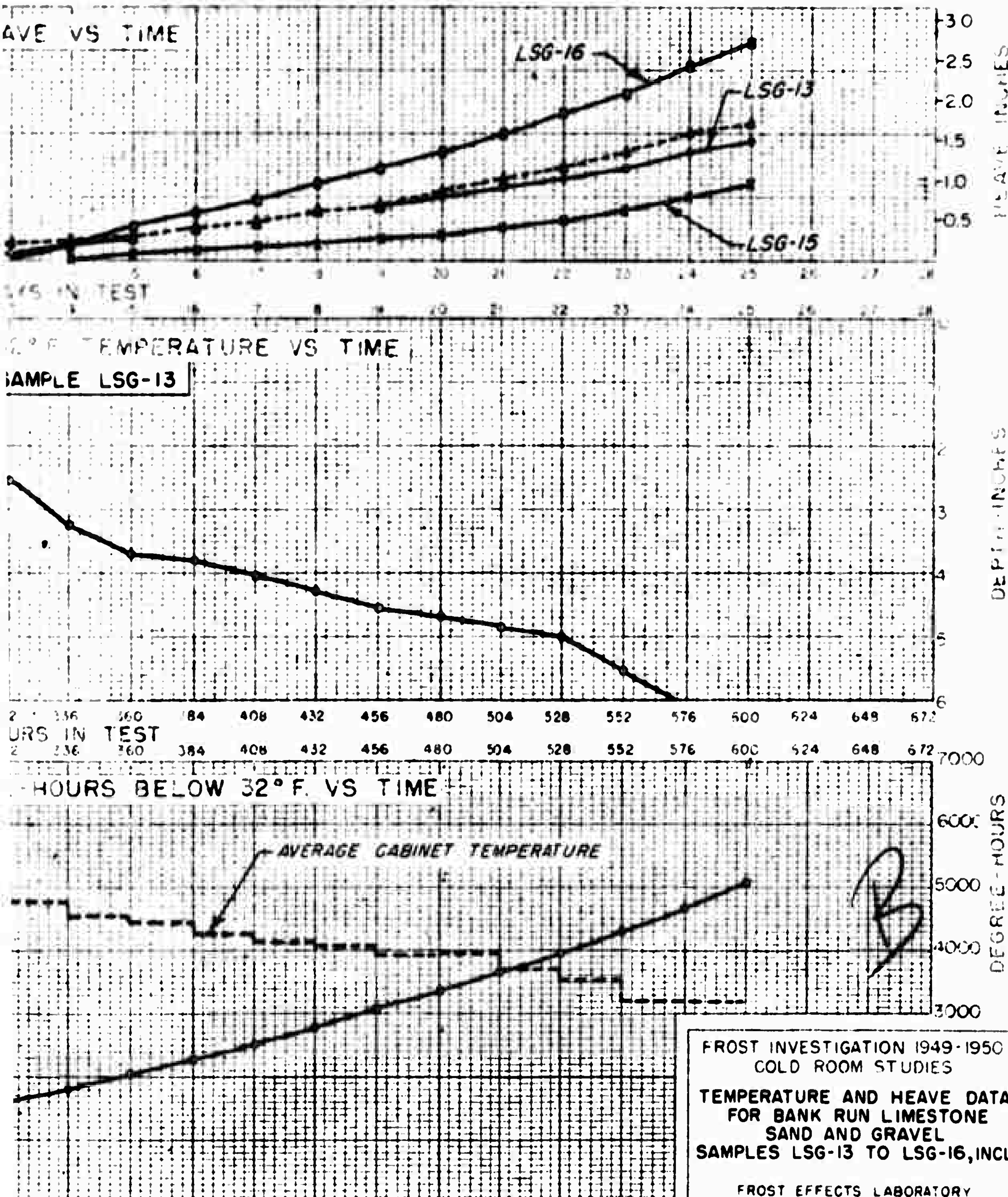
TEMPERATURE AND HEAVE DATA FOR ARTIFICIALLY GRADED LIMESTONE SAND AND GRAVEL SAMPLES LSG-9 TO LSG-12, INCL.

FROST EFFECTS LABORATORY
NEW ENGLAND DIVISION CORPS OF ENGR.
BOSTON, MASS. JULY 1950

PLATE 24



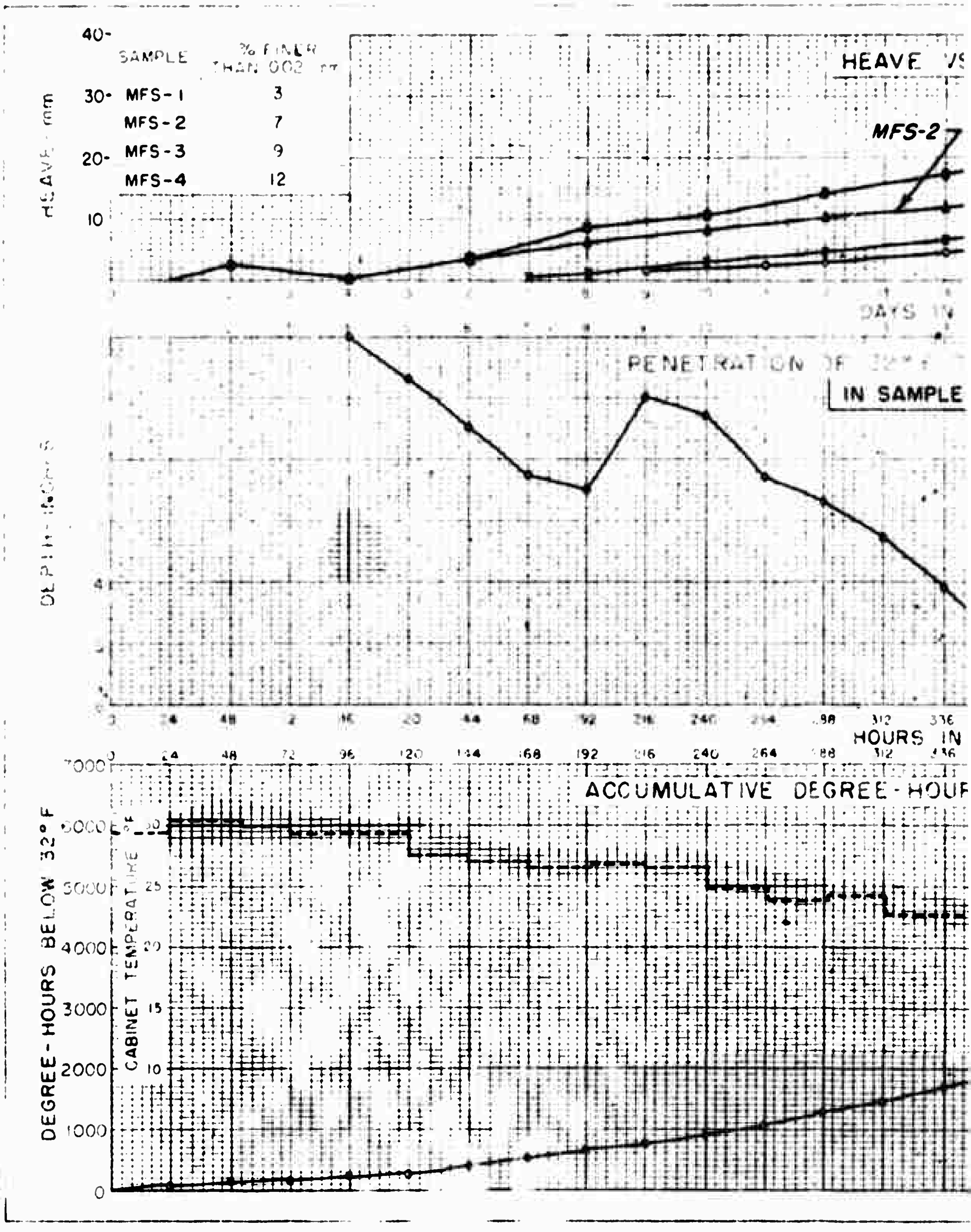
HEAVE - mm
SAMPLE
LSG-13 7
LSG-14 8
LSG-15 10
LSG-16 13
HEAVE
LSG-14
PENETRATION OF 32° F
IN SAMPL
DEPTH - INCHES
HOURS
ACCUMULATIVE DEGREE-HOU
DEGREE-HOURS BELOW 32° F
CABINET TEMPERATURE

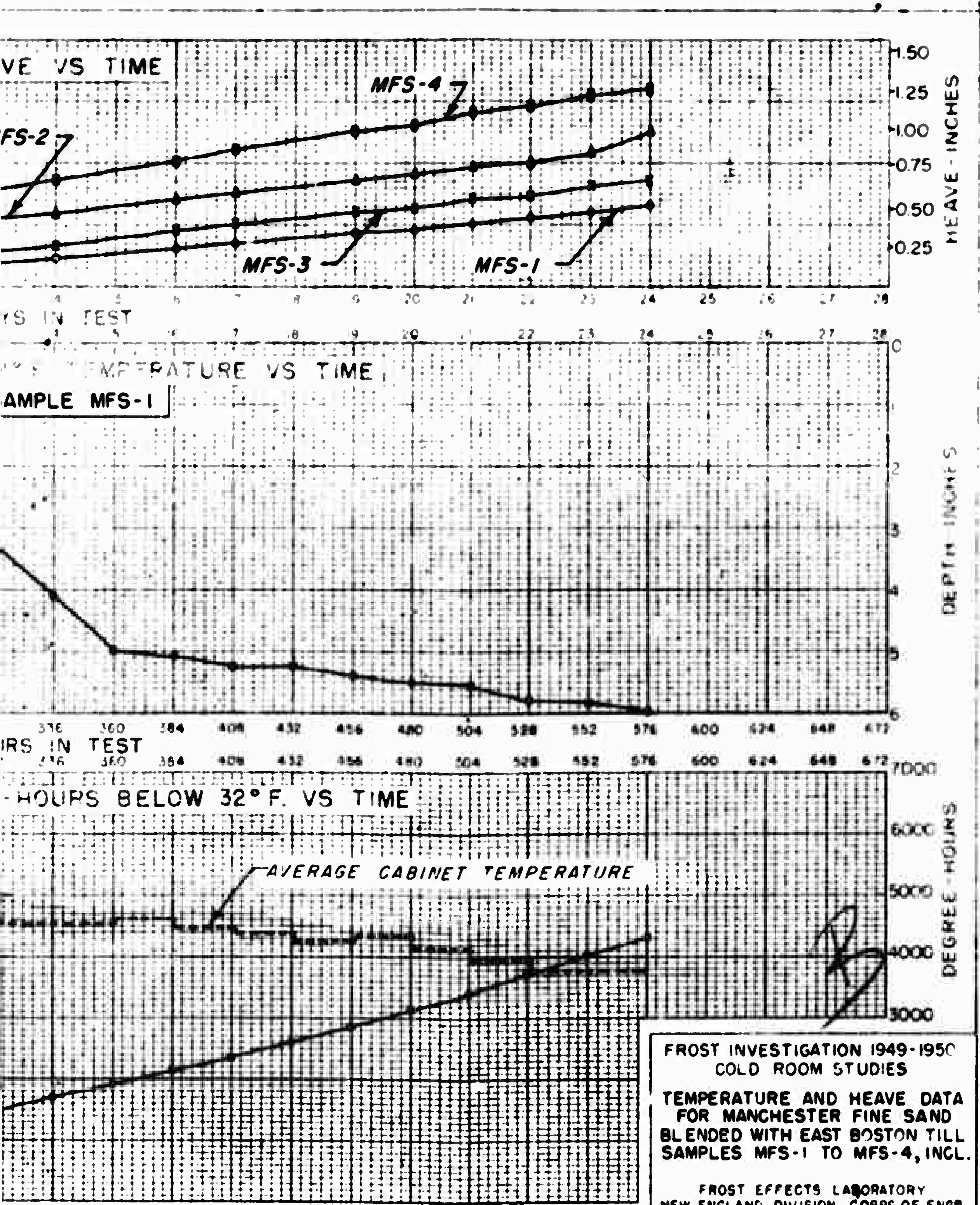


FROST INVESTIGATION 1949-1950
COLD ROOM STUDIES

TEMPERATURE AND HEAVE DATA FOR BANK RUN LIMESTONE SAND AND GRAVEL SAMPLES LSG-13 TO LSG-16, INCL.

FROST EFFECTS LABORATORY
NEW ENGLAND DIVISION CORPS OF ENGR.
BOSTON, MASS. JULY 1950

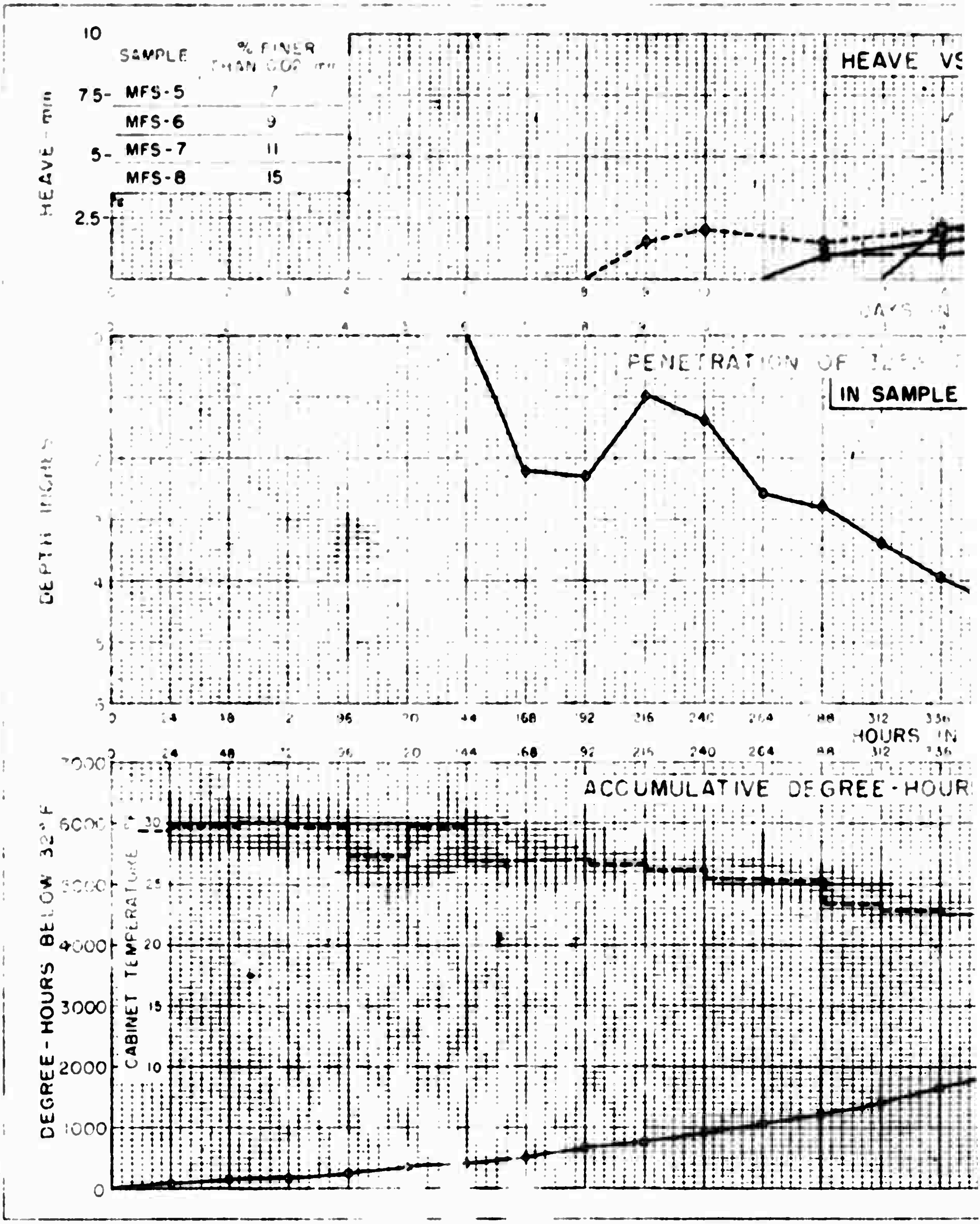

SAMPLE
% FINER THAN .002 mm
MFS-1 3
MFS-2 7
MFS-3 9
MFS-4 12
HEAVE - mm
HEAVE VS
MFS-2
DAYS IN
PENETRATION OF 32°F
IN SAMPLE
HOURS IN
ACCUMULATIVE DEGREE-HOUR
DEGREE-HOURS BELOW 32° F
CABINET TEMPERATURE °F

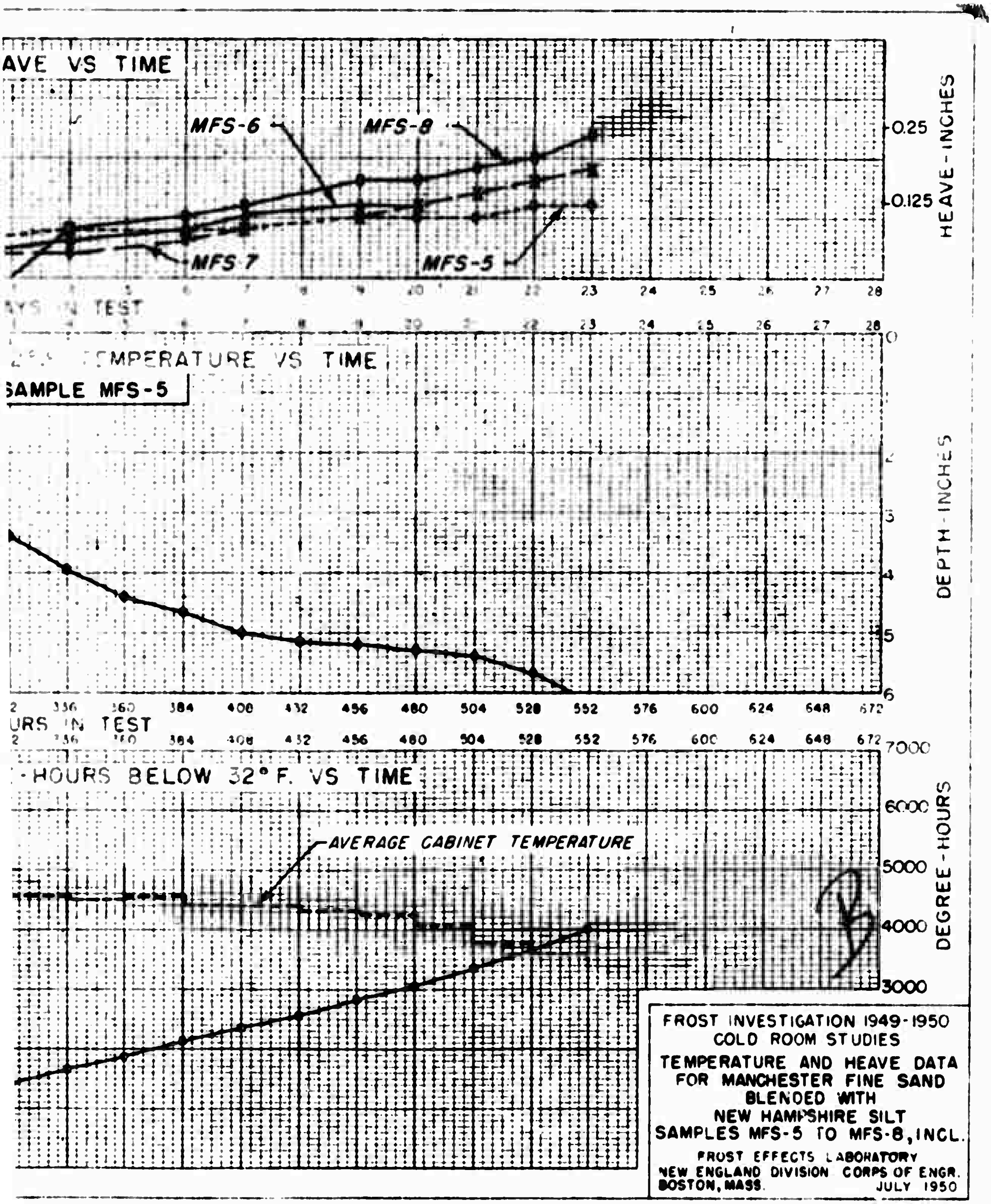


FROST INVESTIGATION 1949-1950
COLD ROOM STUDIES

TEMPERATURE AND HEAVE DATA FOR MANCHESTER FINE SAND BLENDED WITH EAST BOSTON TILL SAMPLES MFS-1 TO MFS-4, INCL.

FROST EFFECTS LABORATORY
NEW ENGLAND DIVISION CORPS OF ENGR.
BOSTON, MASS. JULY 1950

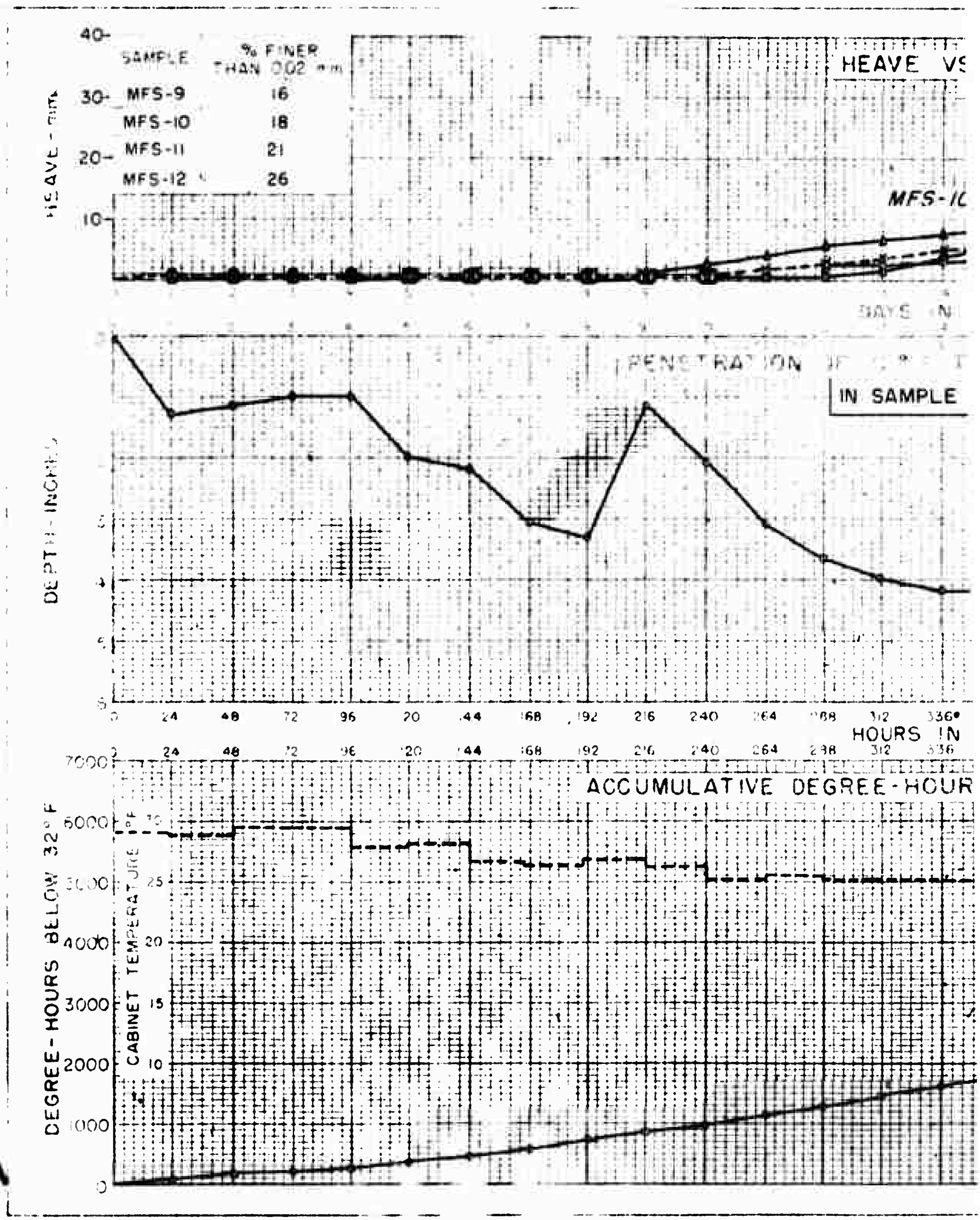

HEAVE VS
SAMPLE
% FINER
MFS-5 7
MFS-6 9
MFS-7 11
MFS-8 15
HEAVE - mm
10
7.5
5
2.5
PENETRATION OF
IN SAMPLE
HOURS IN
ACCUMULATIVE DEGREE - HOUR
DEGREE - HOURS BELOW 32° F
CABINET TEMPERATURE
7000
6000
5000
4000
3000
2000
1000
0
30
25
20
15
10
24
48
96
144
168
192
216
240
264
312
336



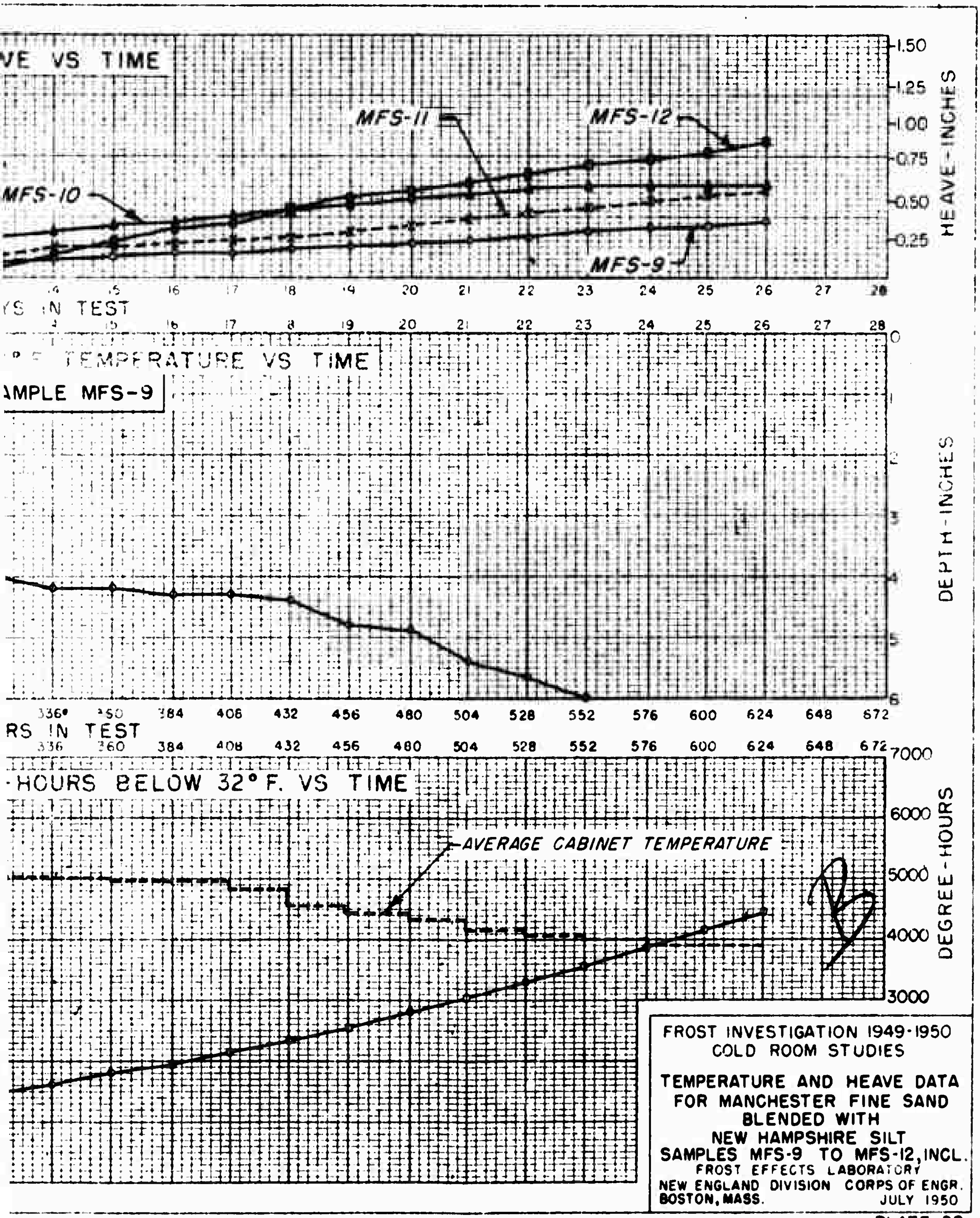
FROST INVESTIGATION 1949-1950
COLD ROOM STUDIES

TEMPERATURE AND HEAVE DATA FOR MANCHESTER FINE SAND BLENDED WITH NEW HAMPSHIRE SILT SAMPLES MFS-5 TO MFS-8, INCL.

FROST EFFECTS LABORATORY
NEW ENGLAND DIVISION CORPS OF ENGR.
BOSTON, MASS. JULY 1950



SAMPLE
% FINER THAN .002 mm
MFS-9 16
MFS-10 18
MFS-11 21
MFS-12 26
HEAVE VS
MFS-10
DAYS IN
IN SAMPLE
DEPTH - INCHES
HOURS IN
ACCUMULATIVE DEGREE-HOUR
DEGREE-HOURS BELOW 32° F
CABINET TEMPERATURE °F

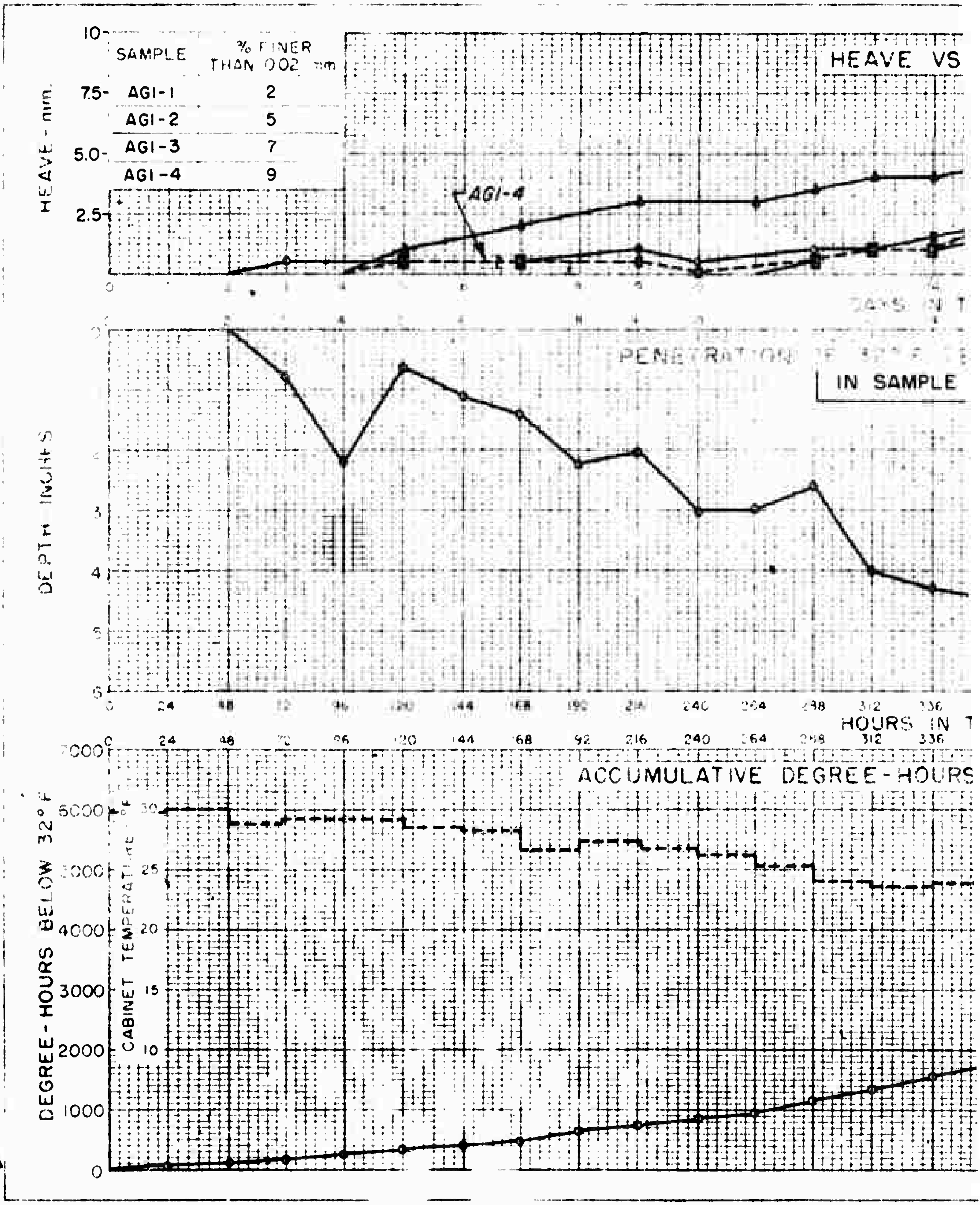


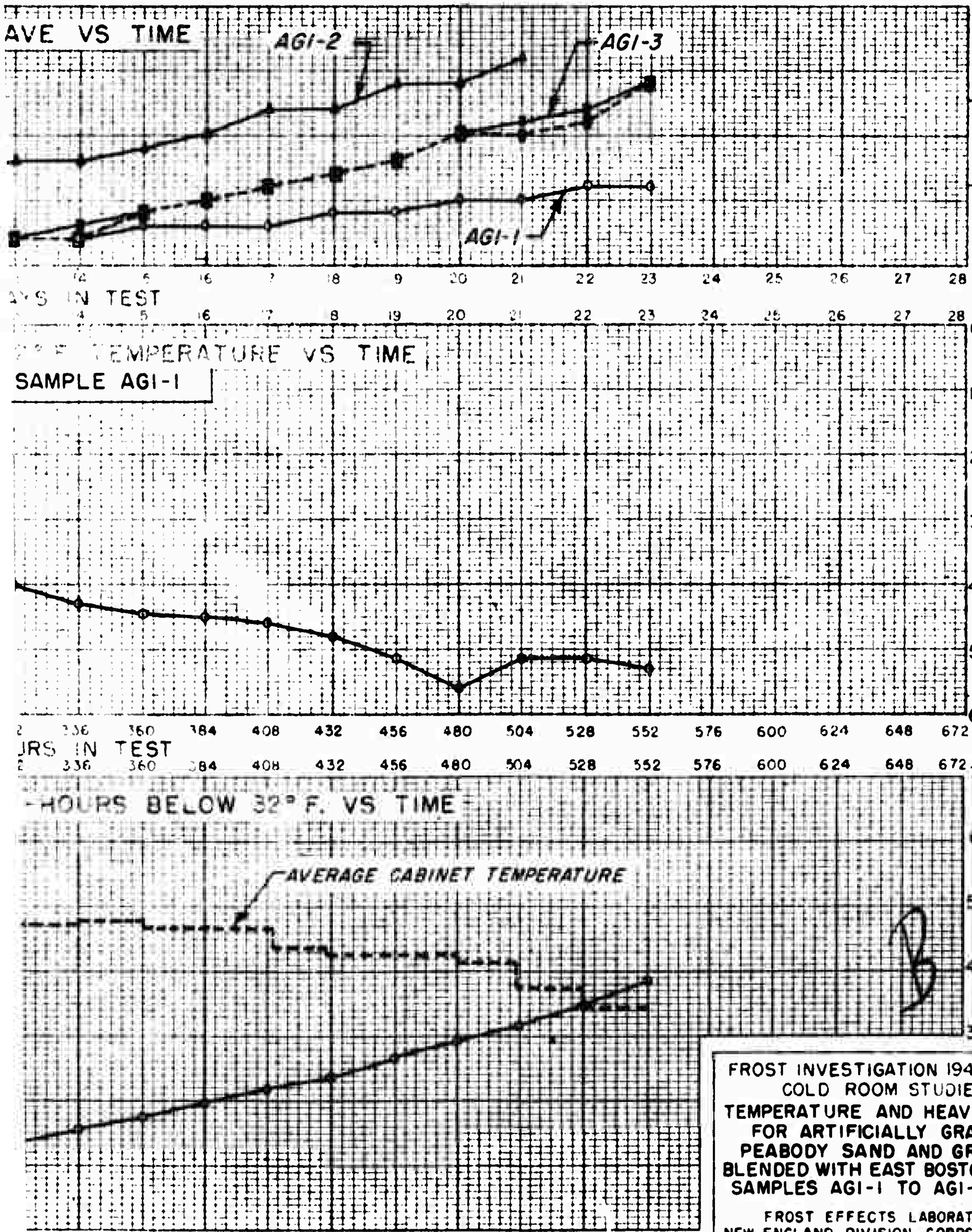
FROST INVESTIGATION 1949-1950
COLD ROOM STUDIES

TEMPERATURE AND HEAVE DATA FOR MANCHESTER FINE SAND BLENDED WITH NEW HAMPSHIRE SILT
SAMPLES MFS-9 TO MFS-12, INCL.

FROST EFFECTS LABORATORY
NEW ENGLAND DIVISION CORPS OF ENGR.
BOSTON, MASS. JULY 1950

PLATE 28

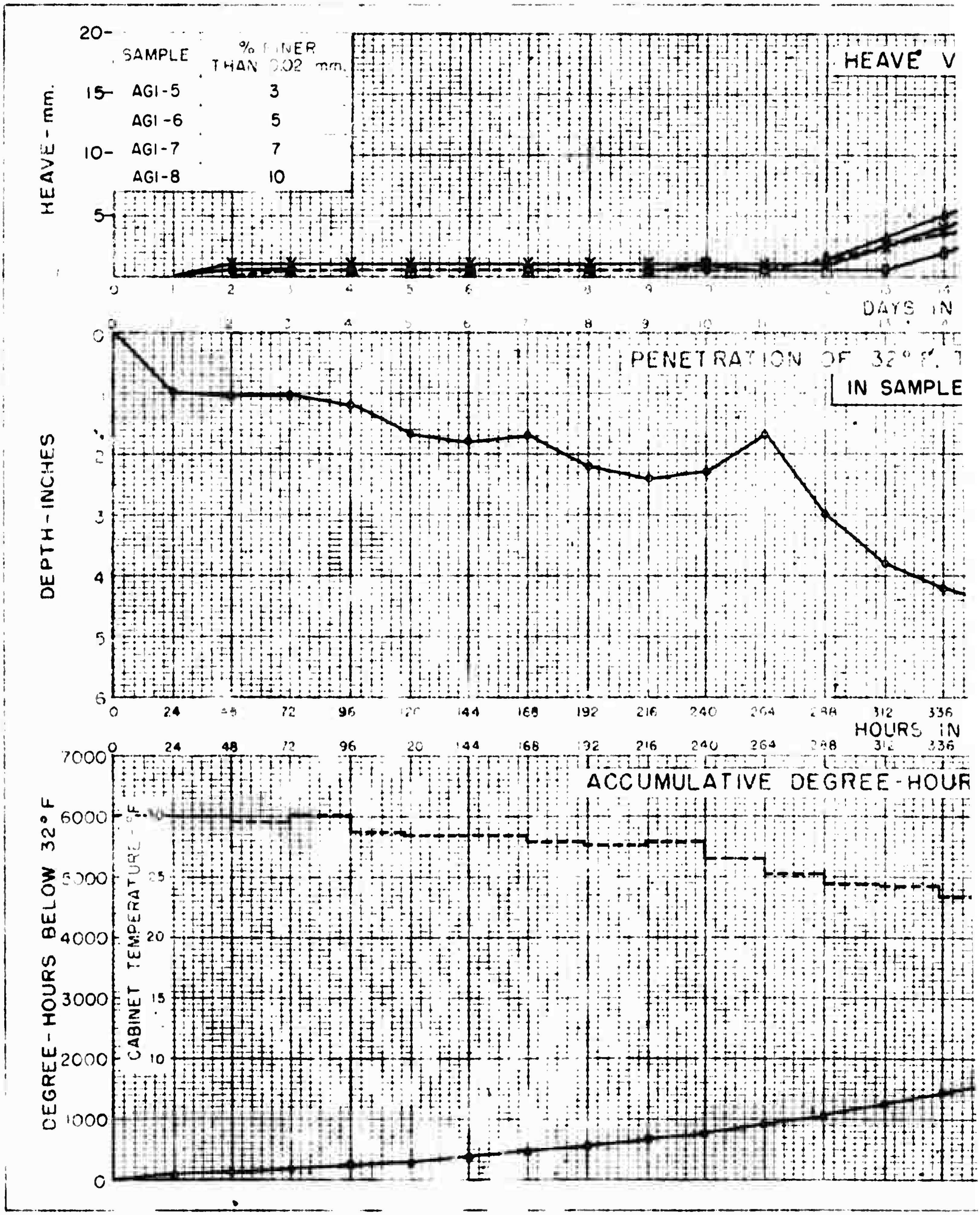

HEAVE VS
SAMPLE
% FINER THAN .002 mm
AGI-1 2
AGI-2 5
AGI-3 7
AGI-4 9
AGI-4
HEAVE - mm.
10
7.5
5.0
2.5
DAYS IN T
IN SAMPLE
DEPTH INCHES
HOURS IN T
0 24 48 72 96 120 144 168 192 216 240 264 288 312 336
ACCUMULATIVE DEGREE-HOURS
DEGREE-HOURS BELOW 32° F
7000
6000
5000
4000
3000
2000
1000
0
CABINET TEMPERATURE °F
30
25
20
15
10



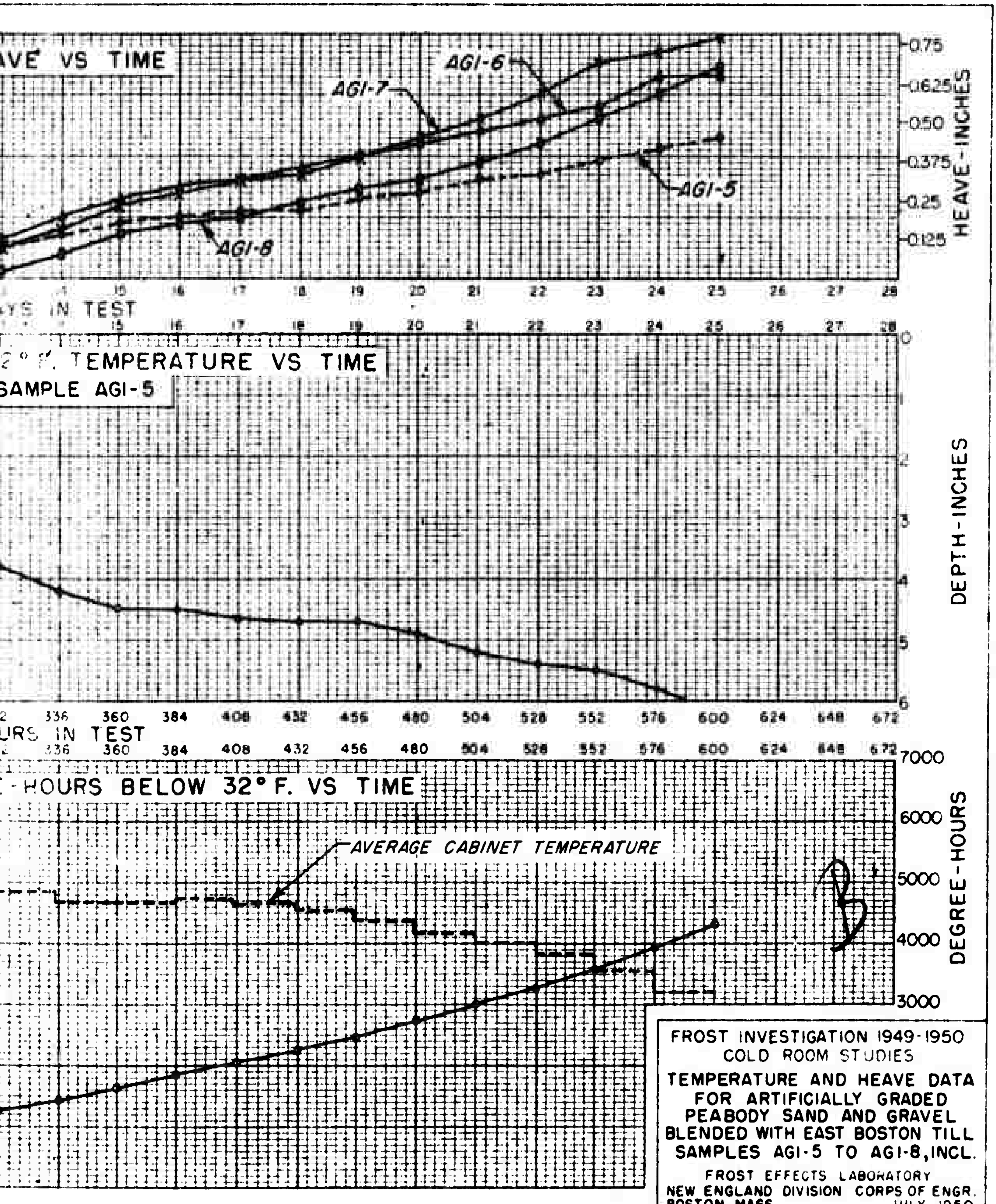
FROST INVESTIGATION 1949-1950
COLD ROOM STUDIES
TEMPERATURE AND HEAVE DATA
FOR ARTIFICIALLY GRADED
PEABODY SAND AND GRAVEL
BLENDED WITH EAST BOSTON TILL
SAMPLES AGI-1 TO AGI-4, INCL.

FROST EFFECTS LABORATORY
NEW ENGLAND DIVISION CORPS OF ENGR.
BOSTON, MASS. JULY 1950

PLATE 2



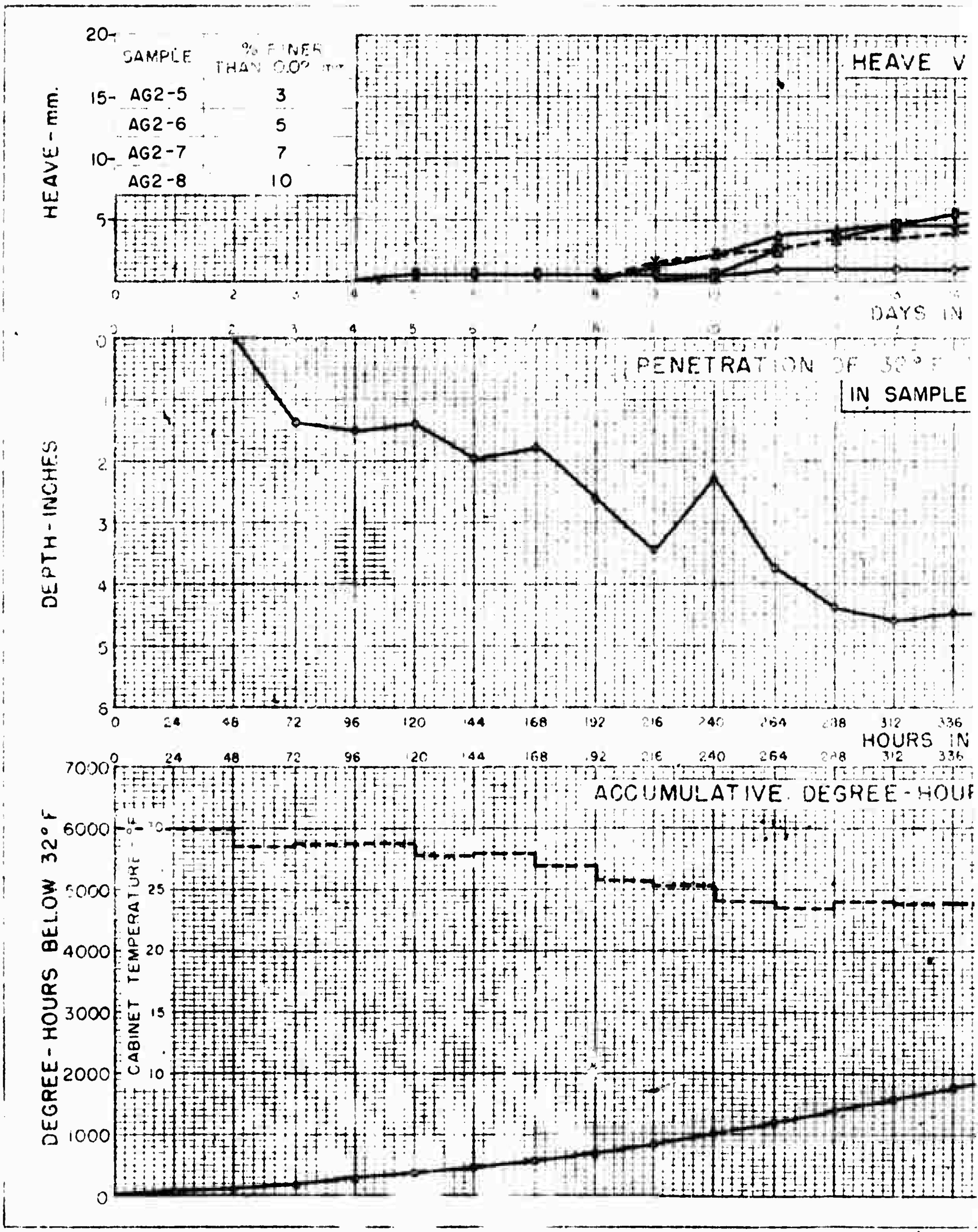
HEAVE V
SAMPLE
% FINER THAN 0.02 mm.
AGI-5 3
AGI-6 5
AGI-7 7
AGI-8 10
HEAVE - mm.
DAYS IN
PENETRATION OF 32° F. T
IN SAMPLE
DEPTH - INCHES
HOURS IN
ACCUMULATIVE DEGREE-HOUR
DEGREE - HOURS BELOW 32° F
CABINET TEMPERATURE - °F



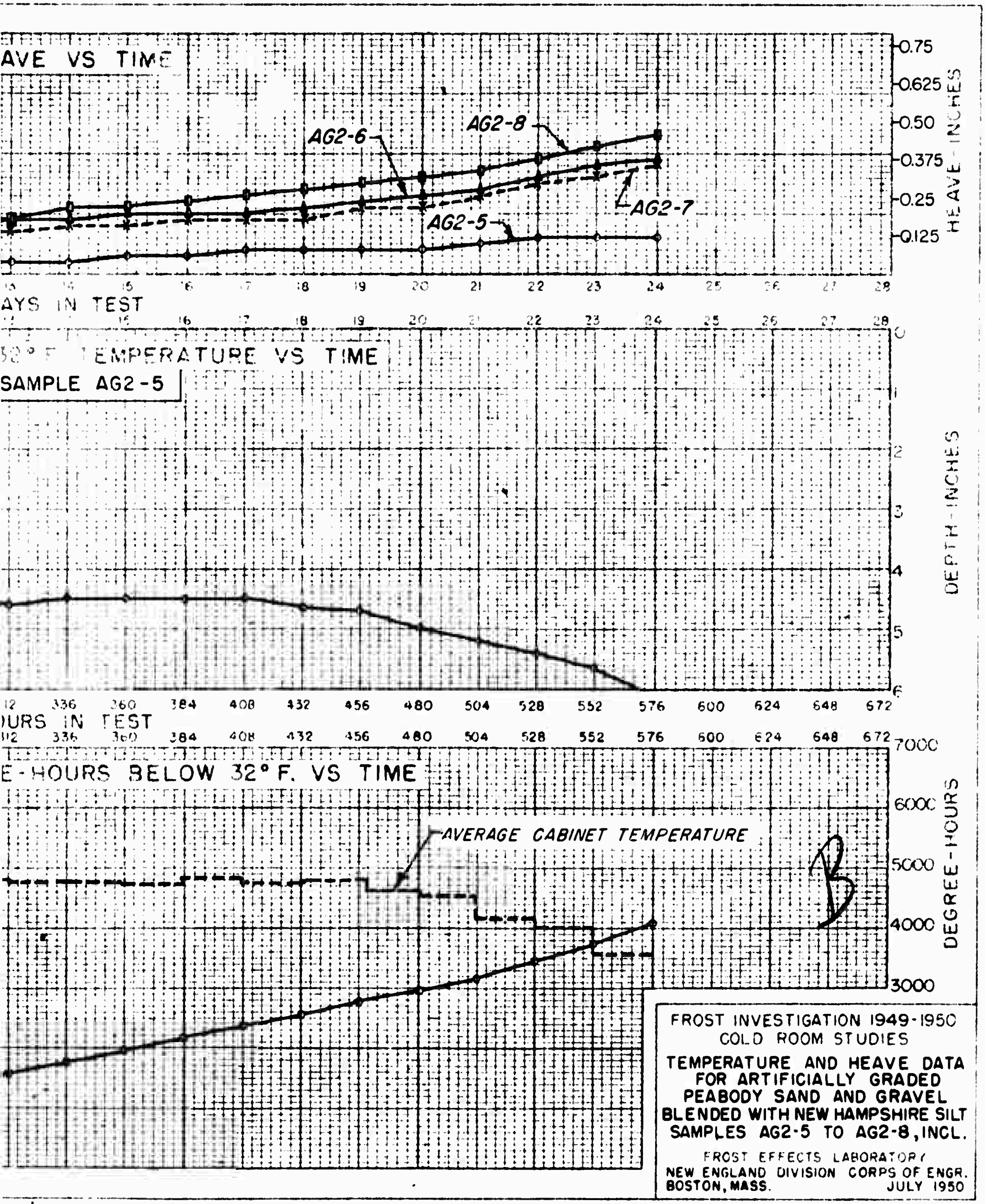
FROST INVESTIGATION 1949-1950
COLD ROOM STUDIES

TEMPERATURE AND HEAVE DATA FOR ARTIFICIALLY GRADED PEABODY SAND AND GRAVEL BLENDED WITH EAST BOSTON TILL SAMPLES AGI-5 TO AGI-8, INCL.

FROST EFFECTS LABORATORY
NEW ENGLAND DIVISION CORPS OF ENGR.
BOSTON, MASS. JULY 1950



HEAVE - mm.
SAMPLE
% FINER THAN 0.02 mm
AG2-5 3
AG2-6 5
AG2-7 7
AG2-8 10
HEAVE V
DAYS IN
DEPTH - INCHES
PENETRATION OF 32°F
IN SAMPLE
HOURS IN
DEGREE-HOURS BELOW 32°F
CABINET TEMPERATURE - °F
ACCUMULATIVE DEGREE-HOUR

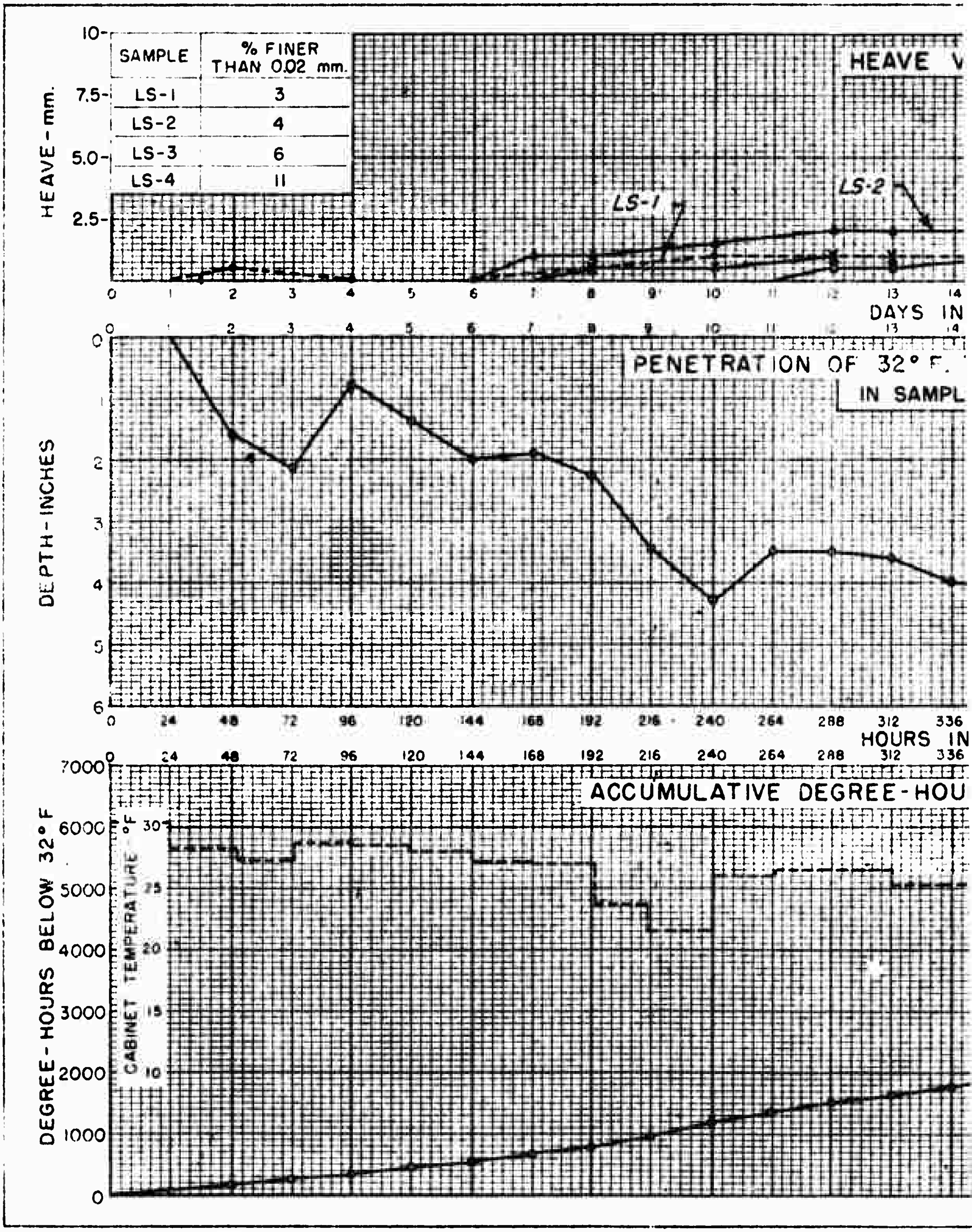


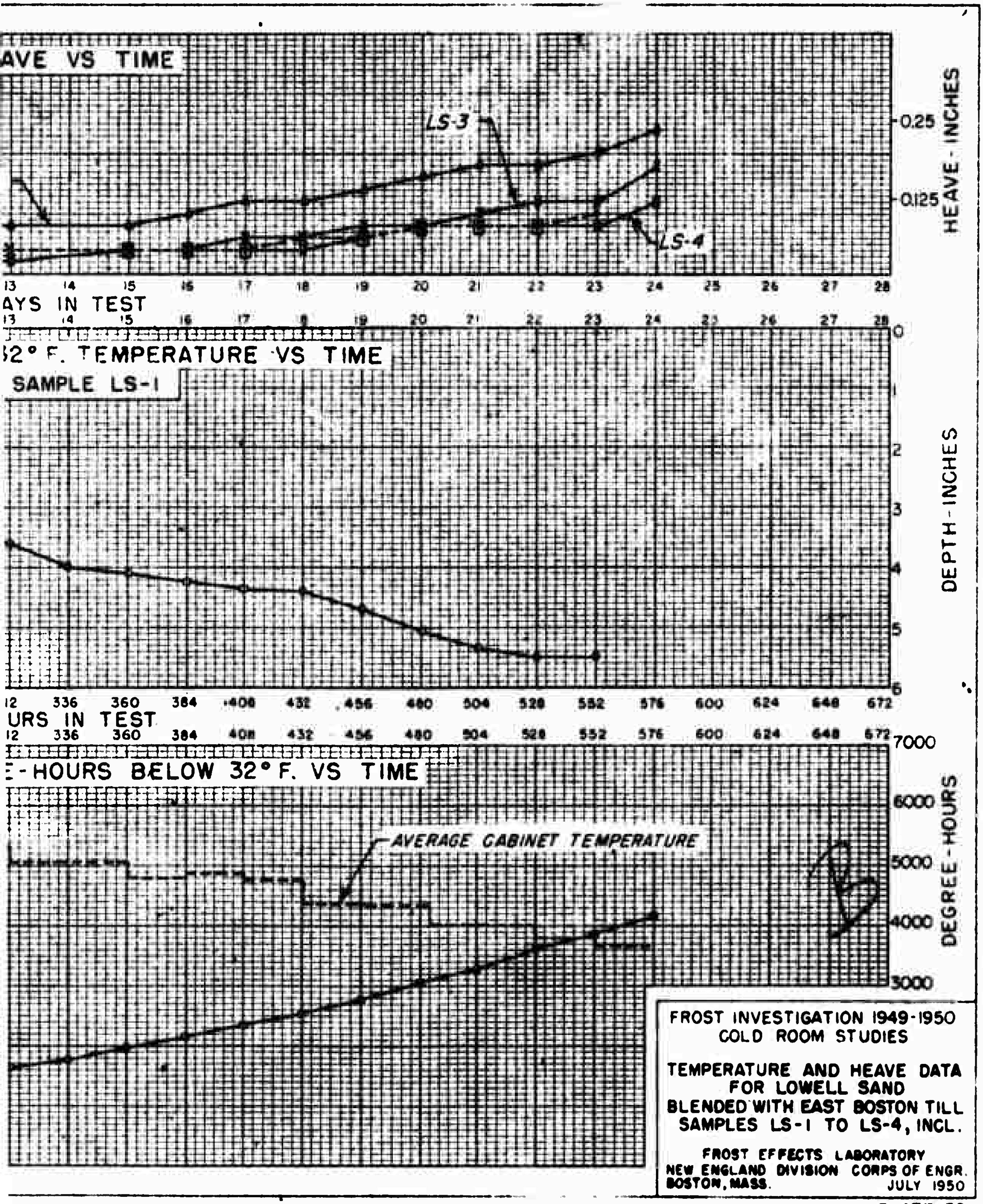
FROST INVESTIGATION 1949-1950
COLD ROOM STUDIES

TEMPERATURE AND HEAVE DATA FOR ARTIFICIALLY GRADED PEABODY SAND AND GRAVEL BLENDED WITH NEW HAMPSHIRE SILT SAMPLES AG2-5 TO AG2-8, INCL.

FROST EFFECTS LABORATORY
NEW ENGLAND DIVISION CORPS OF ENGR.
BOSTON, MASS. JULY 1950

PLATE 31


SAMPLE
% FINER THAN 0.02 mm.
LS-1 3
LS-2 4
LS-3 6
LS-4 11
HEAVE-mm.
HEAVE V
LS-1
LS-2
DAYS IN
DEPTH-INCHES
PENETRATION OF 32° F.
IN SAMPL
HOURS IN
DEGREE-HOURS BELOW 32° F
CABINET TEMPERATURE - °F
ACCUMULATIVE DEGREE-HOU

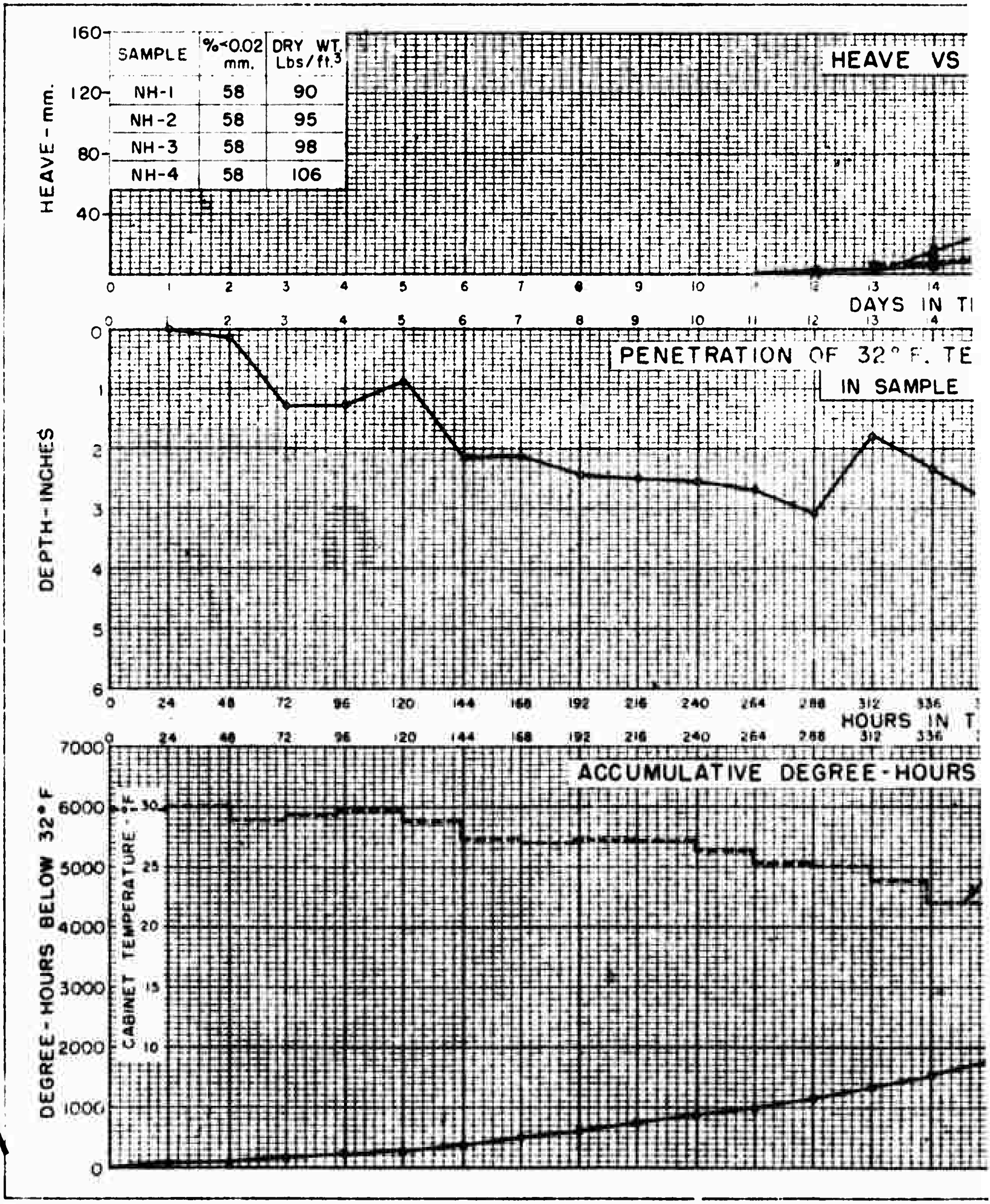


FROST INVESTIGATION 1949-1950
COLD ROOM STUDIES

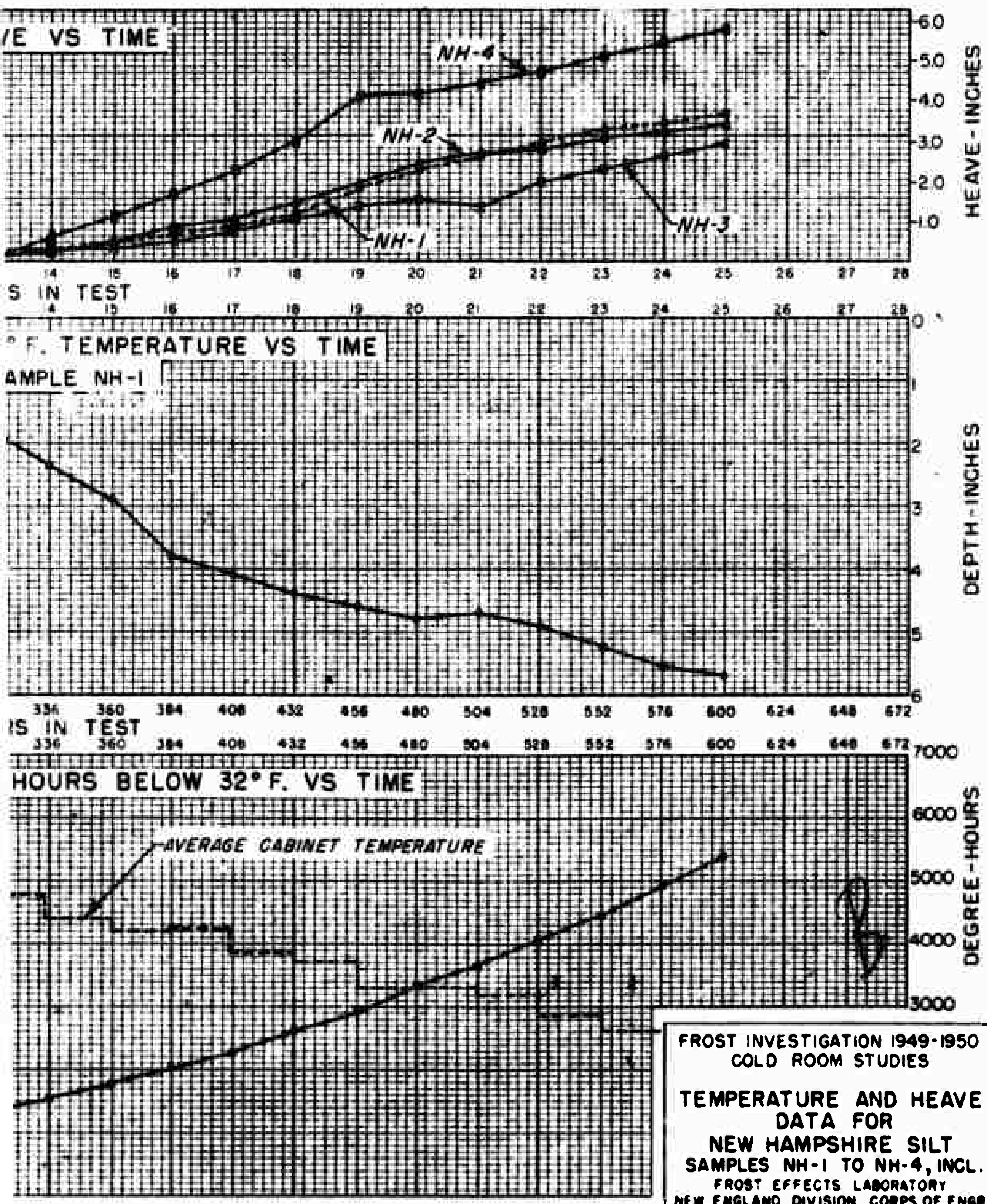
TEMPERATURE AND HEAVE DATA
FOR LOWELL SAND
BLENDED WITH EAST BOSTON TILL
SAMPLES LS-1 TO LS-4, INCL.

FROST EFFECTS LABORATORY
NEW ENGLAND DIVISION CORPS OF ENGR.
BOSTON, MASS. JULY 1950

PLATE 32



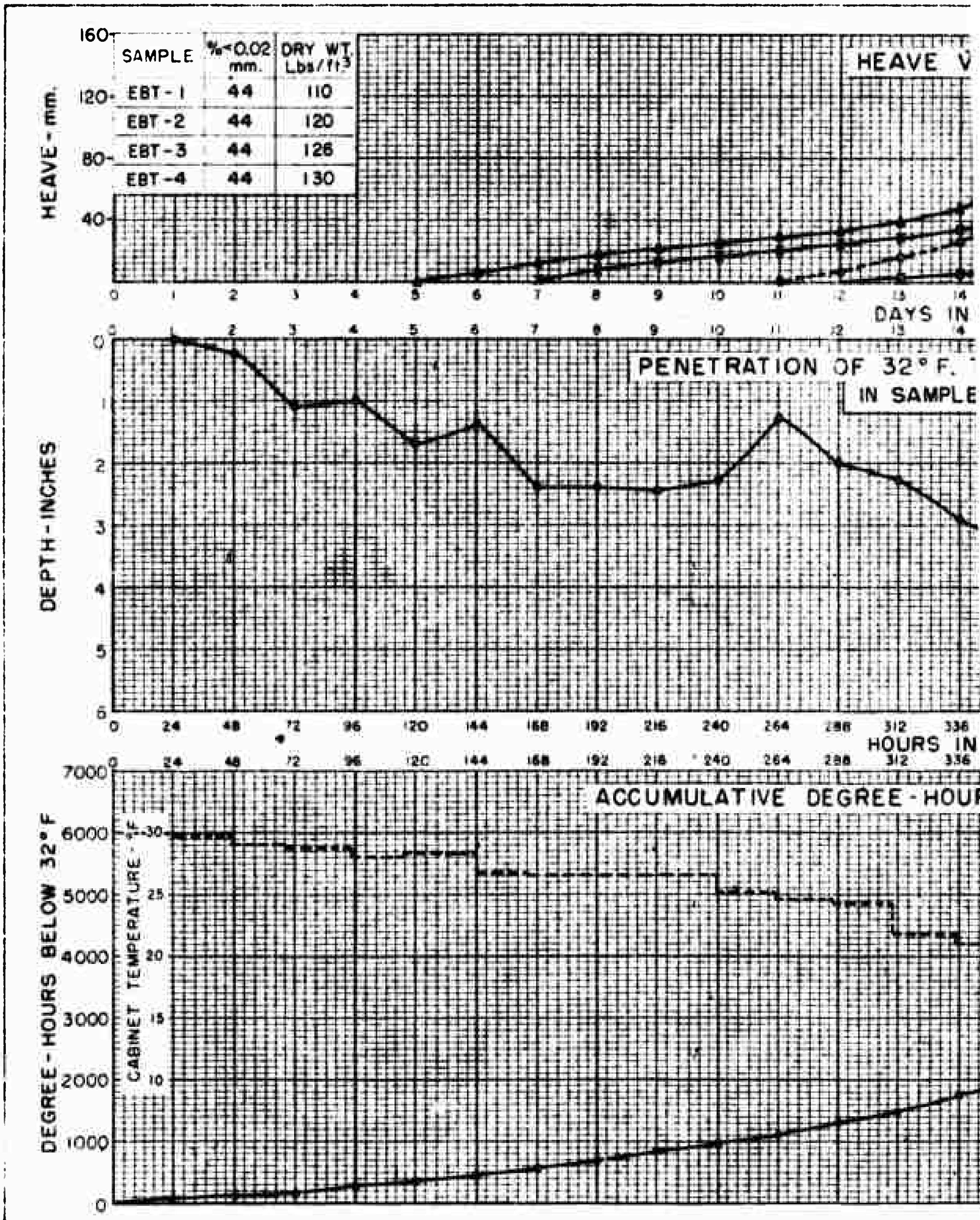
HEAVE VS
SAMPLE
%<0.02 mm.
DRY WT. Lbs/ft.3
NH-1 58 90
NH-2 58 95
NH-3 58 98
NH-4 58 106
HEAVE - mm.
DAYS IN TI
PENETRATION OF 32° F. TE
IN SAMPLE
DEPTH - INCHES
HOURS IN T
ACCUMULATIVE DEGREE-HOURS
DEGREE-HOURS BELOW 32° F
CABINET TEMPERATURE - °F



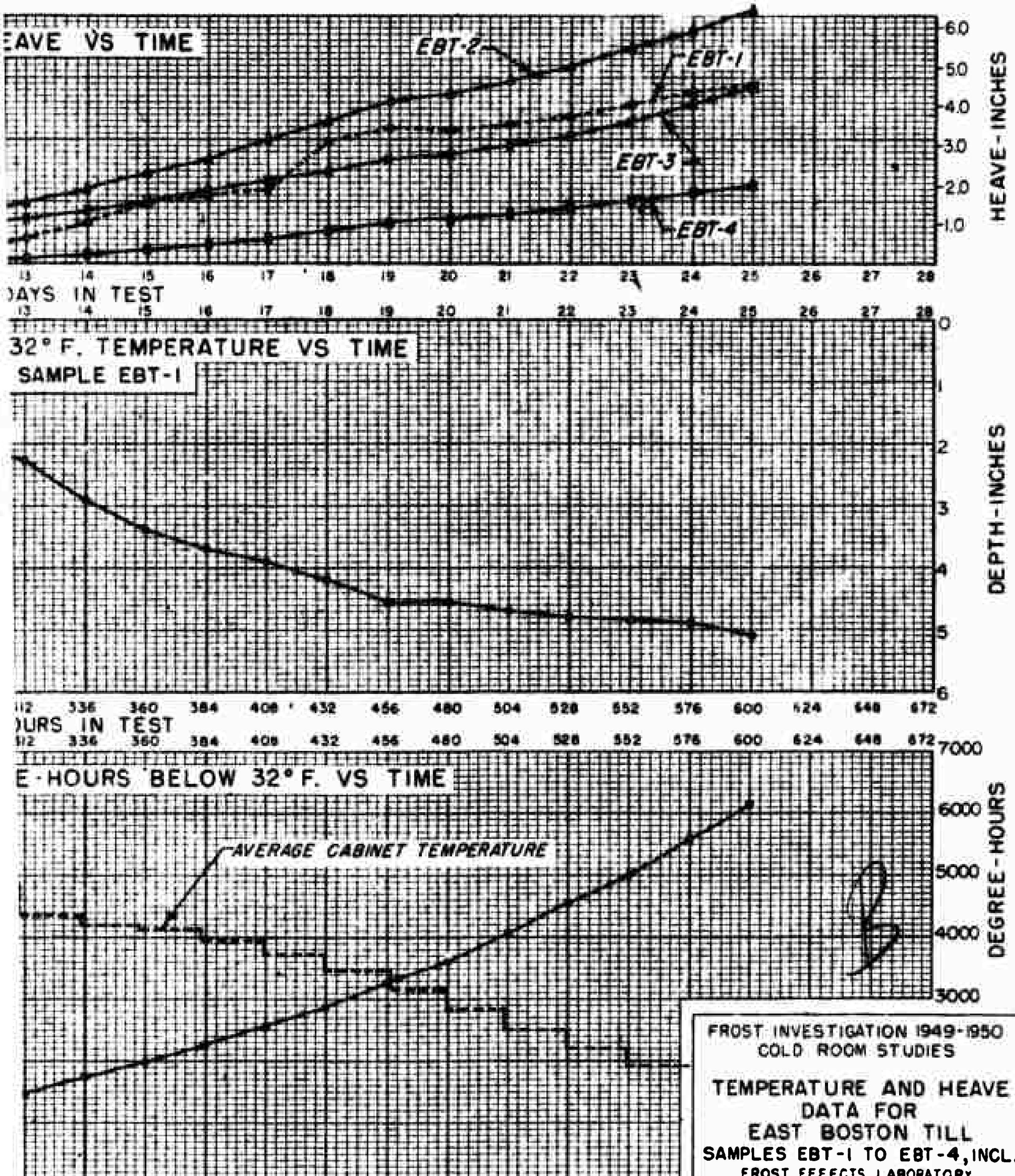
FROST INVESTIGATION 1949-1950
COLD ROOM STUDIES

TEMPERATURE AND HEAVE DATA FOR NEW HAMPSHIRE SILT
SAMPLES NH-1 TO NH-4, INCL.

FROST EFFECTS LABORATORY
NEW ENGLAND DIVISION CORPS OF ENGR.
BOSTON, MASS. JULY 1950



HEAVE V
SAMPLE
%<0.02 mm.
DRY WT. Lbs/ft³
EBT - 1 44 110
EBT - 2 44 120
EBT - 3 44 126
EBT - 4 44 130
HEAVE - mm.
DAYS IN
PENETRATION OF 32° F.
IN SAMPLE
DEPTH - INCHES
HOURS IN
ACCUMULATIVE DEGREE - HOUR
DEGREE - HOURS BELOW 32° F
CABINET TEMPERATURE - °F

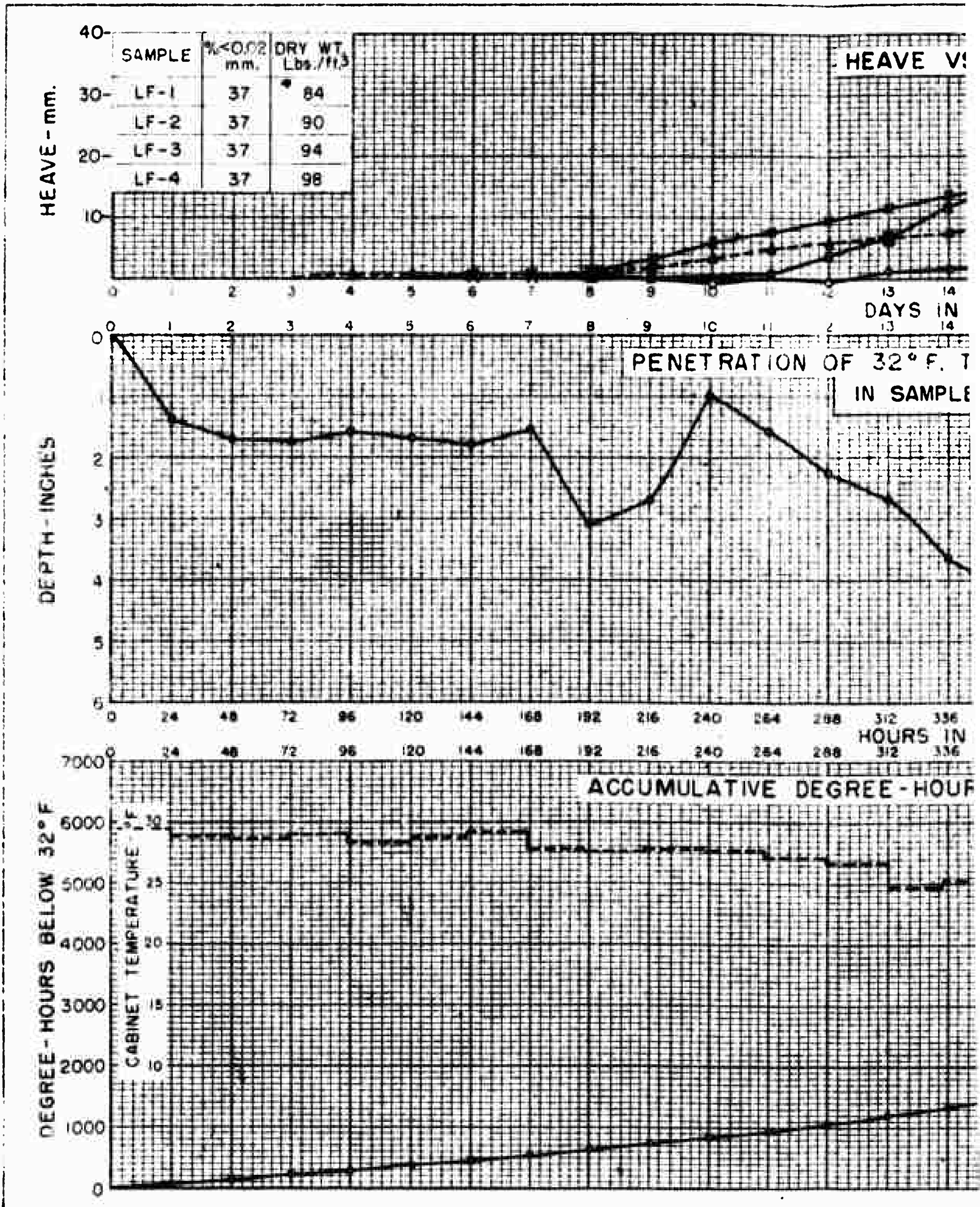


FROST INVESTIGATION 1949-1950
COLD ROOM STUDIES

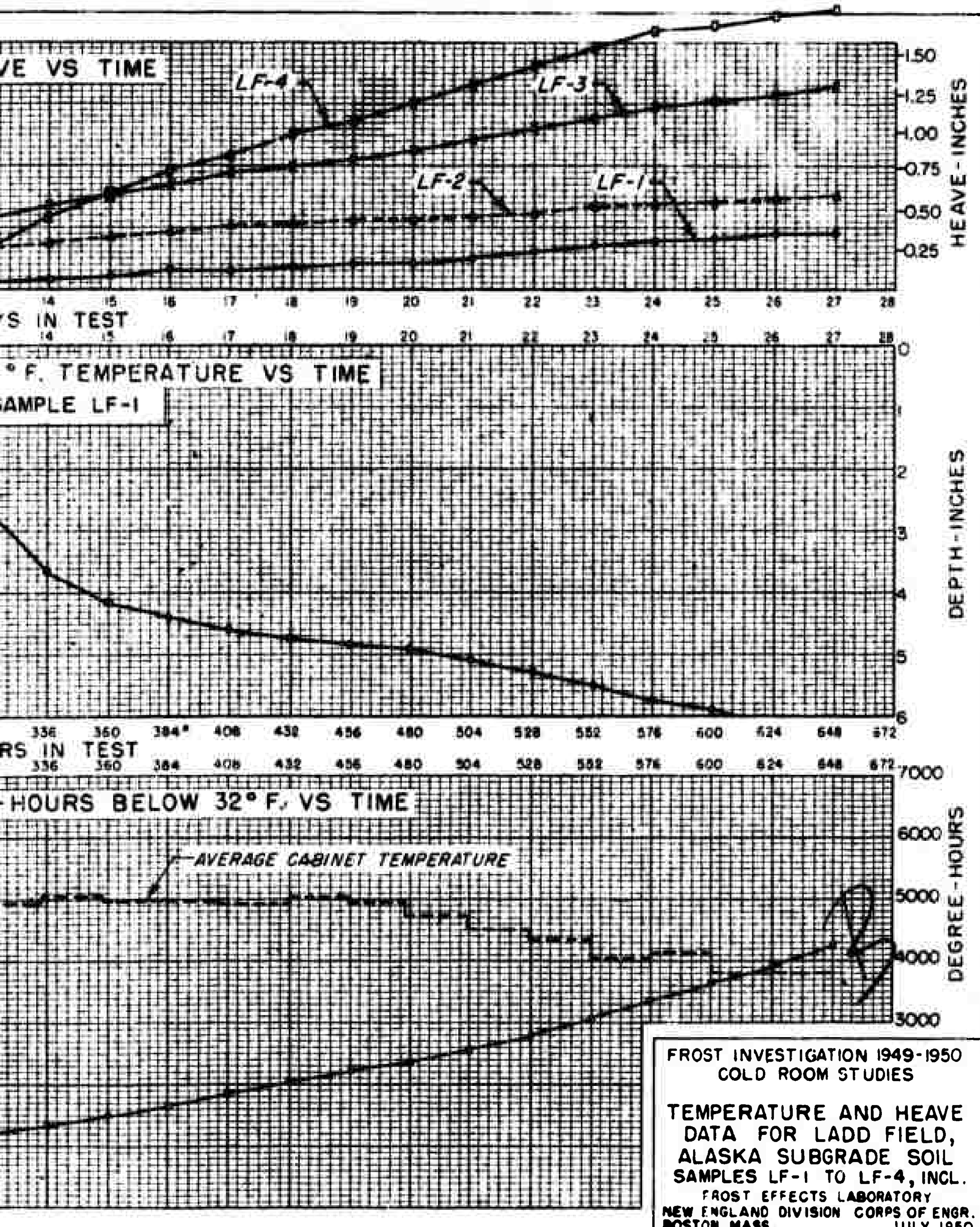
TEMPERATURE AND HEAVE
DATA FOR
EAST BOSTON TILL
SAMPLES EBT-1 TO EBT-4, INCL.

FROST EFFECTS LABORATORY
NEW ENGLAND DIVISION CORPS OF ENGR.
BOSTON, MASS. JULY 1950

PLATE 34



HEAVE VS
SAMPLE
%<0.02 mm.
DRY WT. Lbs./ft.3
LF-1 37 84
LF-2 37 90
LF-3 37 94
LF-4 37 98
HEAVE - mm.
DAYS IN
PENETRATION OF 32° F. T
IN SAMPLE
DEPTH - INCHES
HOURS IN
ACCUMULATIVE DEGREE-HOUR
DEGREE-HOURS BELOW 32° F
CABINET TEMPERATURE °F

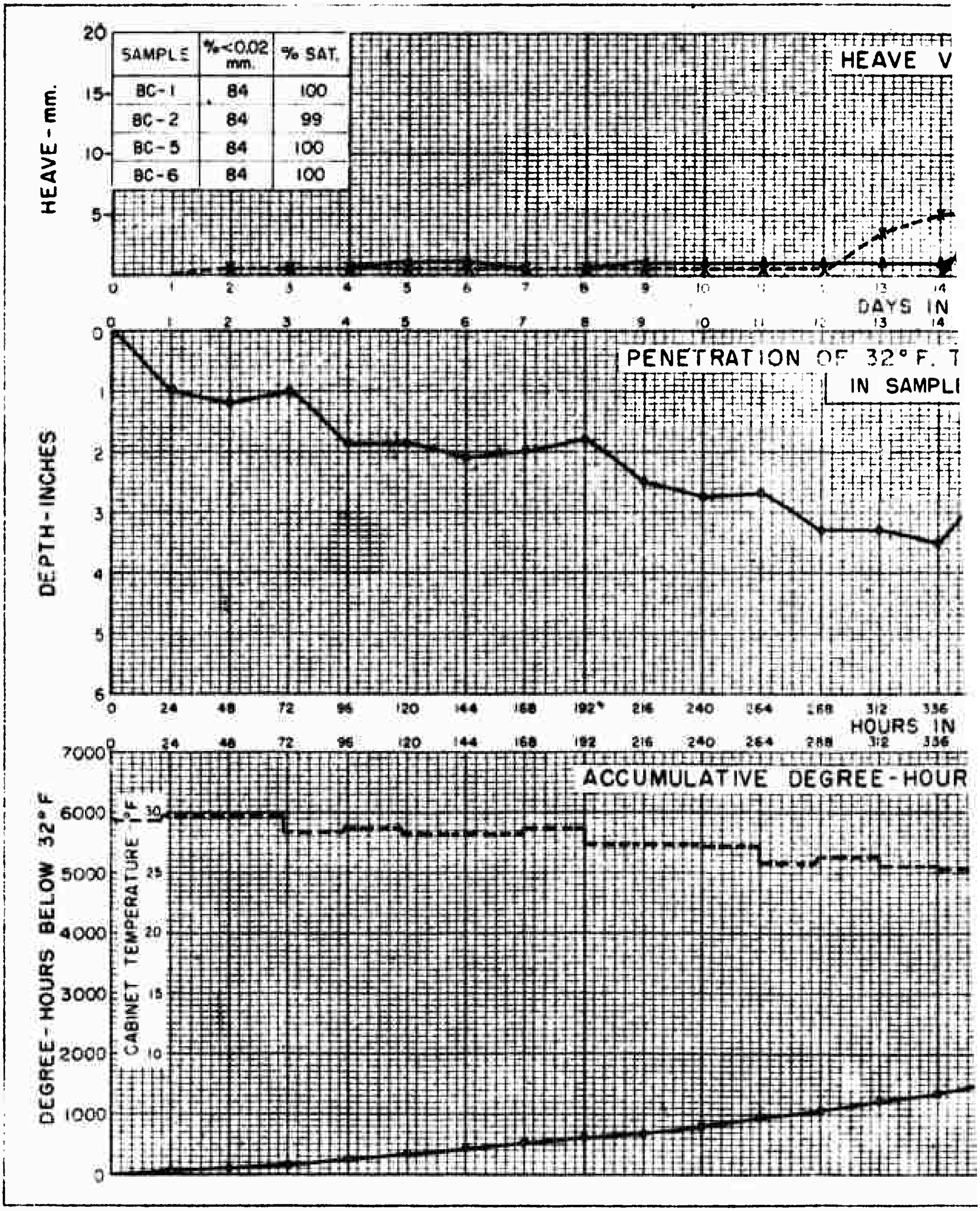


FROST INVESTIGATION 1949-1950
COLD ROOM STUDIES

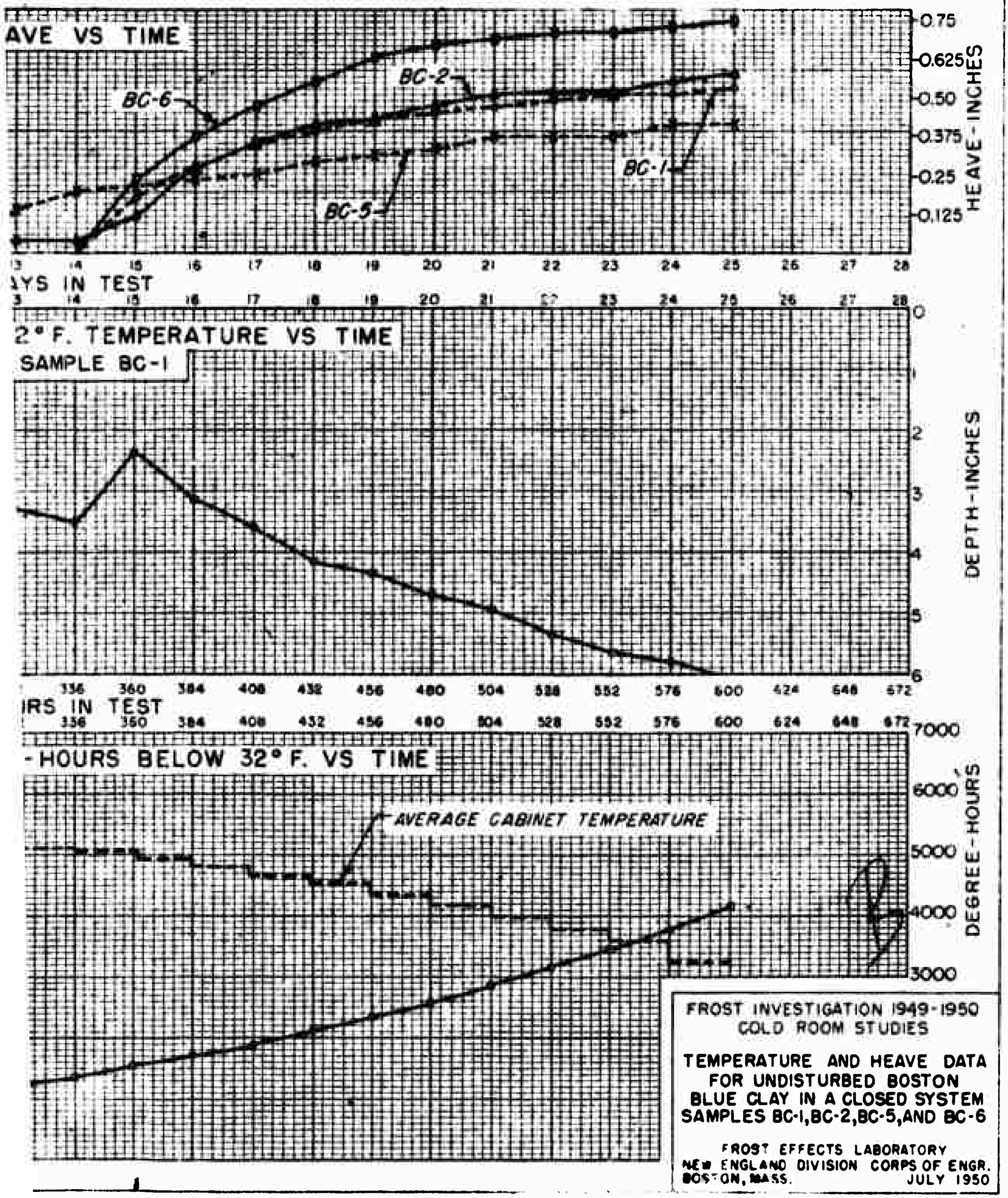
TEMPERATURE AND HEAVE DATA FOR LADD FIELD, ALASKA SUBGRADE SOIL SAMPLES LF-1 TO LF-4, INCL.

FROST EFFECTS LABORATORY
NEW ENGLAND DIVISION CORPS OF ENGR.
BOSTON, MASS. JULY 1950

PLATE 37



HEAVE VS
HEAVE - mm.
SAMPLE
% < 0.02 mm.
% SAT.
BC-1
BC-2
BC-5
BC-6
84
100
99
DAYS IN
PENETRATION OF 32° F. T
IN SAMPLE
DEPTH - INCHES
HOURS IN
ACCUMULATIVE DEGREE-HOUR
DEGREE-HOURS BELOW 32° F
CABINET TEMPERATURE - °F

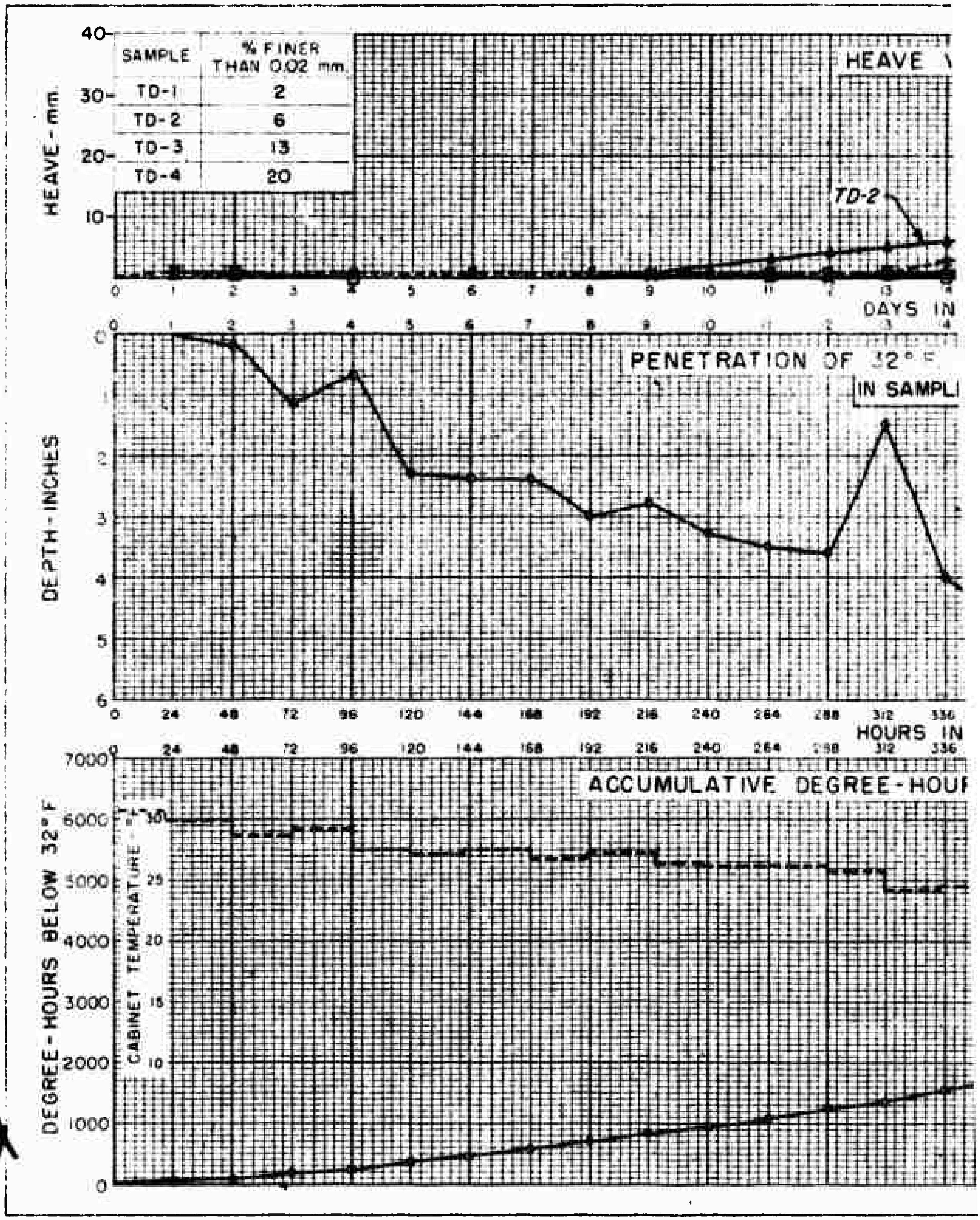


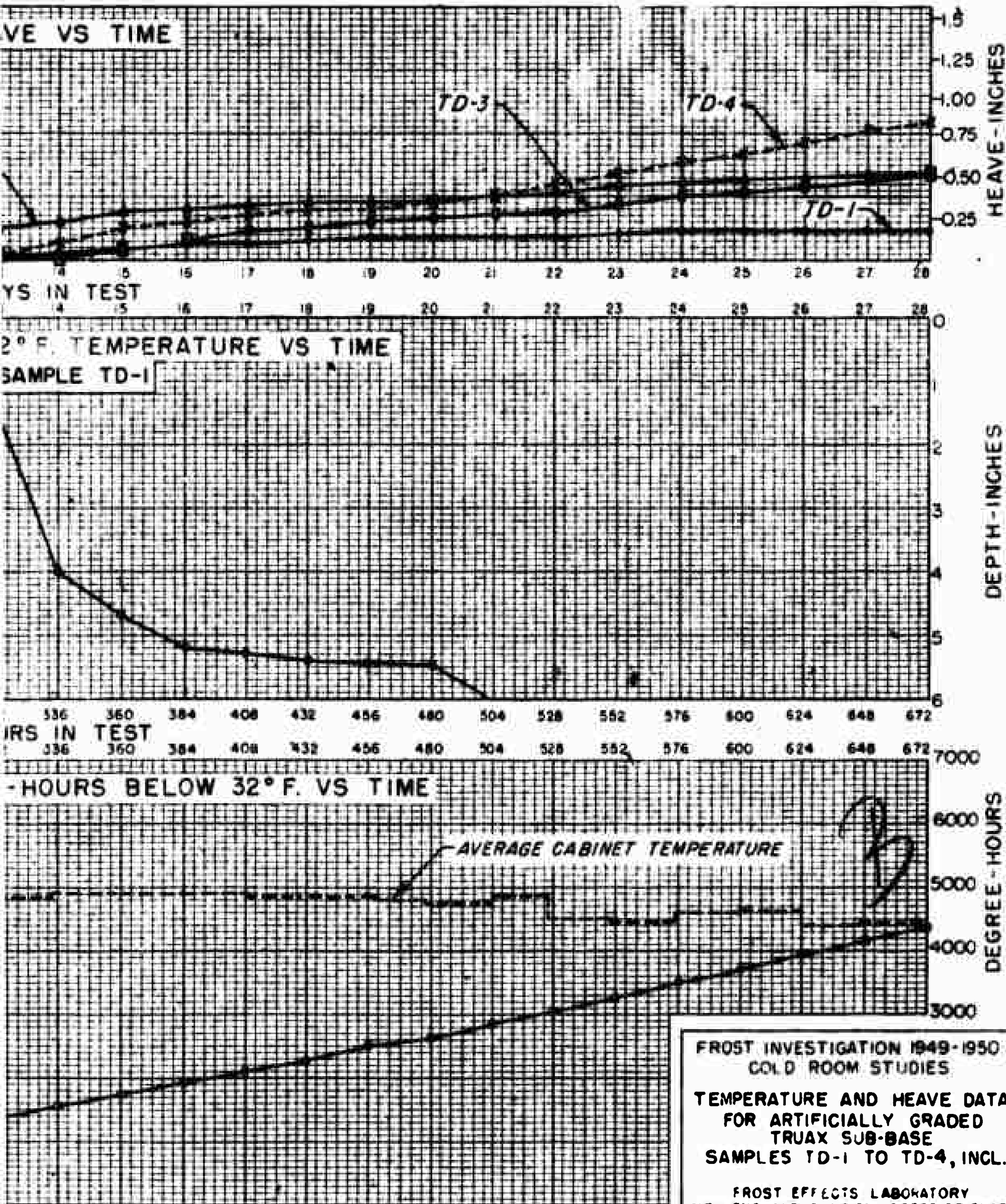
FROST INVESTIGATION 1949-1950
COLD ROOM STUDIES

TEMPERATURE AND HEAVE DATA FOR UNDISTURBED BOSTON BLUE CLAY IN A CLOSED SYSTEM SAMPLES BC-1, BC-2, BC-5, AND BC-6

FROST EFFECTS LABORATORY
NEW ENGLAND DIVISION CORPS OF ENGR.
BOSTON, MASS. JULY 1950

PLATE 36


SAMPLE
% FINER THAN 0.02 mm.
TD-1 2
TD-2 6
TD-3 13
TD-4 20
HEAVE
HEAVE - mm.
TD-2
DAYS IN
PENETRATION OF 32° F
IN SAMPL
DEPTH - INCHES
HOURS IN
ACCUMULATIVE DEGREE-HOUR
DEGREE - HOURS BELOW 32° F
CABINET TEMPERATURE - °F

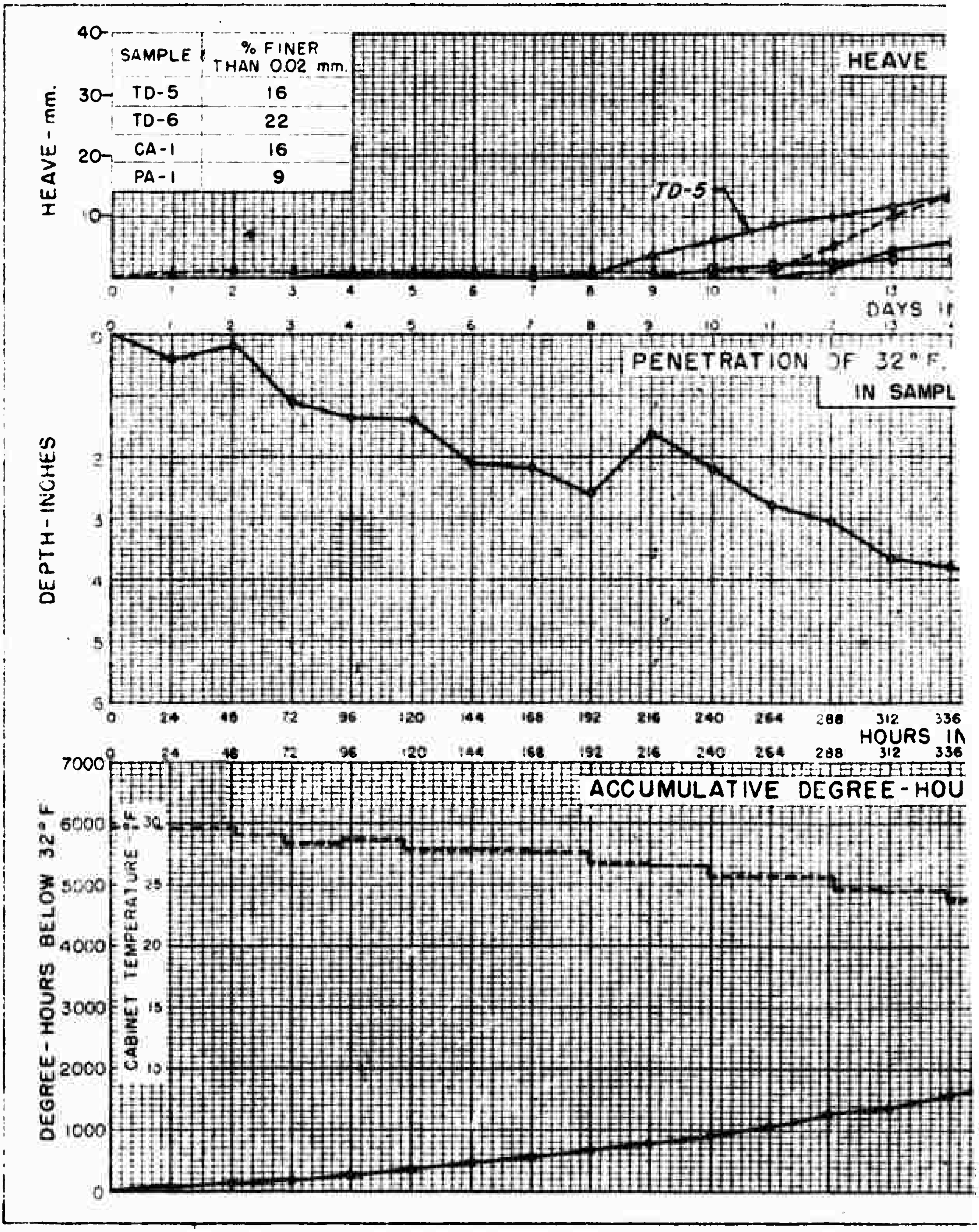


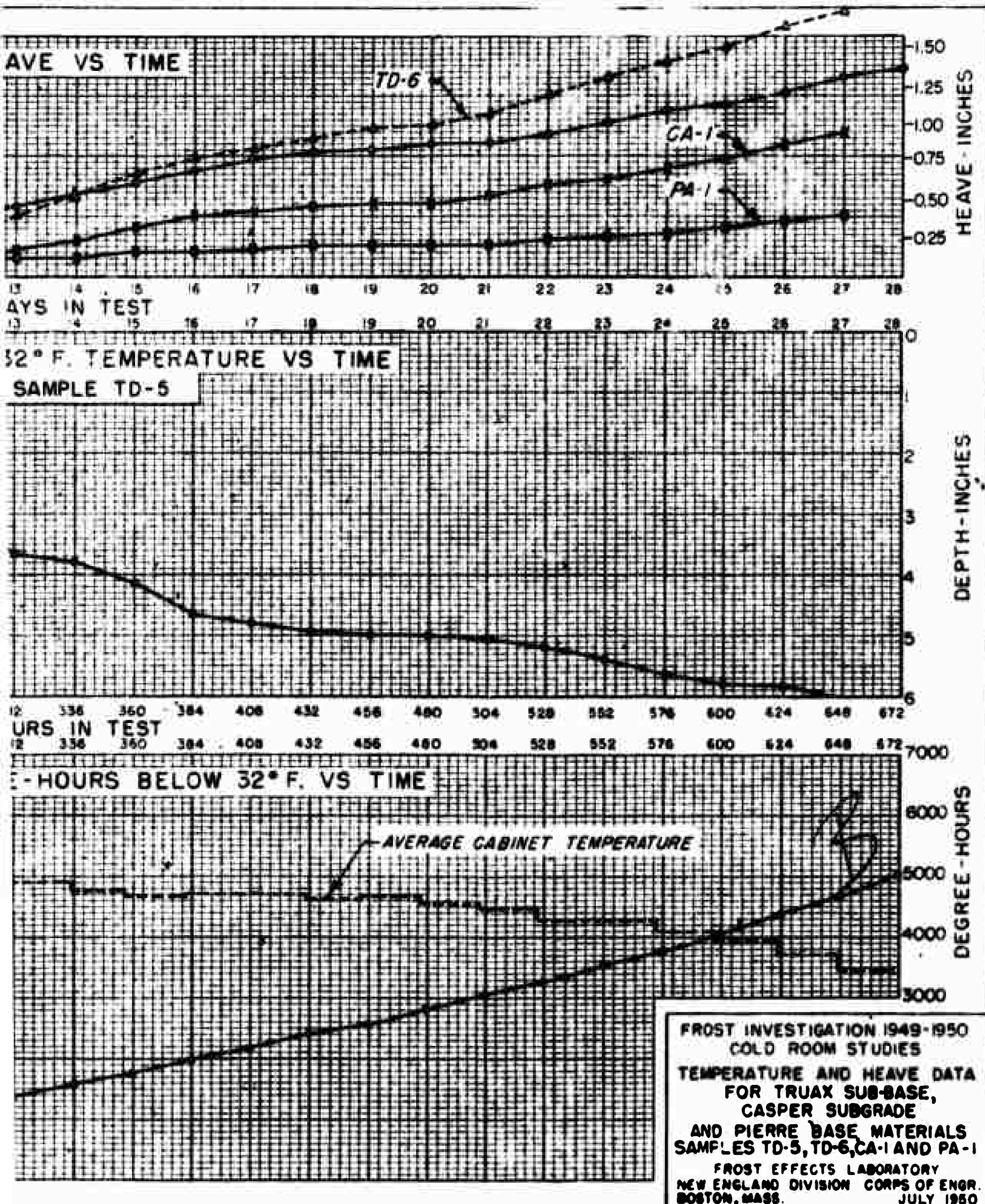
FROST INVESTIGATION 1949-1950
COLD ROOM STUDIES

TEMPERATURE AND HEAVE DATA
FOR ARTIFICIALLY GRADED
TRUAX SUB-BASE
SAMPLES TD-1 TO TD-4, INCL.

FROST EFFECTS LABORATORY
NEW ENGLAND DIVISION CORPS OF ENGR.
BOSTON, MASS. JULY 1950

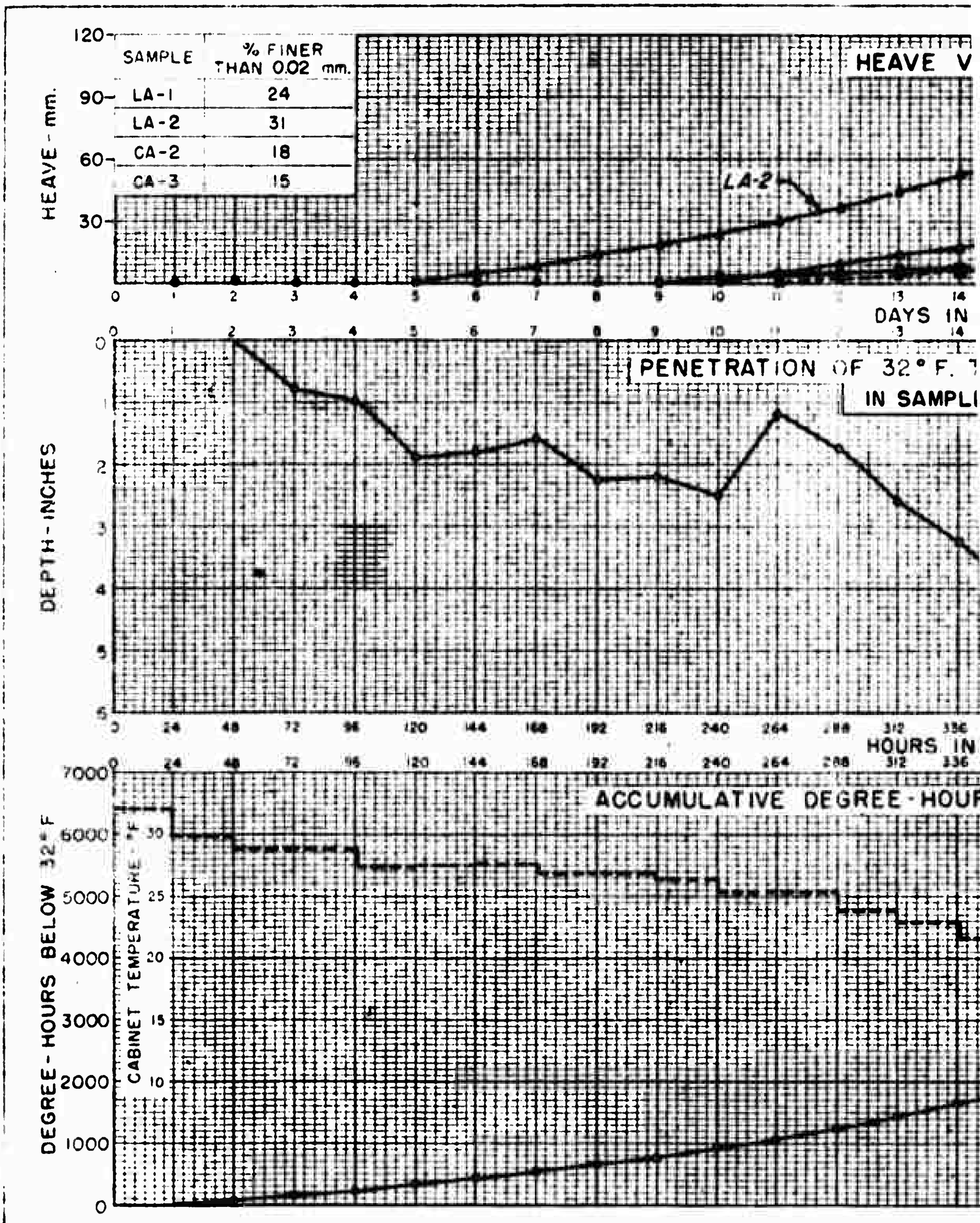
PLATE 37

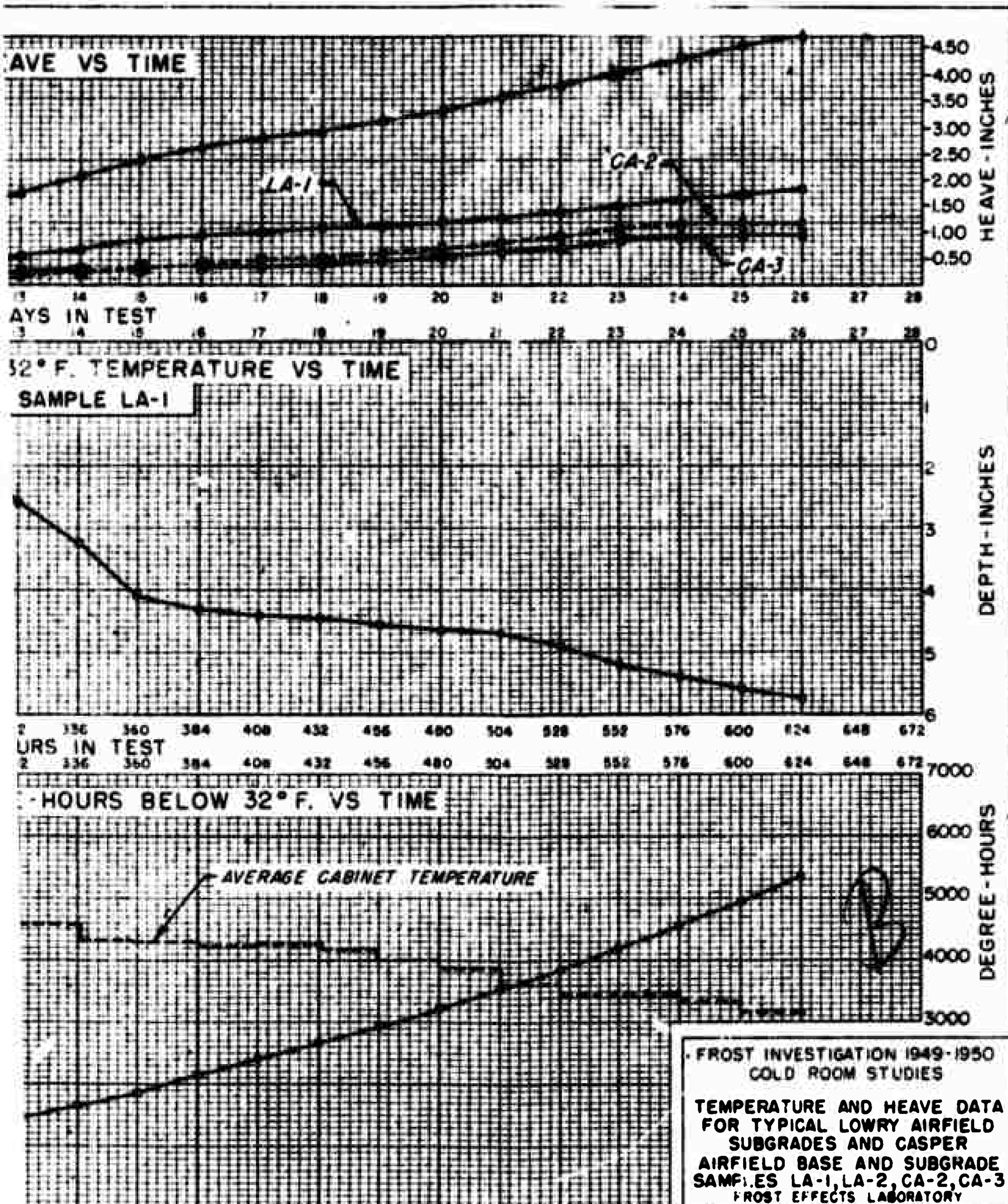

SAMPLE
% FINER THAN 0.02 mm.
TD-5 16
TD-6 22
CA-1 16
PA-1 9
HEAVE
HEAVE - mm.
TD-5
DAYS IN
PENETRATION OF 32° F.
IN SAMPL
DEPTH - INCHES
HOURS IN
ACCUMULATIVE DEGREE-HOU
DEGREE - HOURS BELOW 32° F
CABINET TEMPERATURE - °F



FROST INVESTIGATION 1949-1950
COLD ROOM STUDIES
TEMPERATURE AND HEAVE DATA
FOR TRUAX SUB-BASE,
CASPER SUBGRADE
AND PIERRE BASE MATERIALS
SAMPLES TD-5, TD-6, CA-1 AND PA-1
FROST EFFECTS LABORATORY
NEW ENGLAND DIVISION CORPS OF ENGR.
BOSTON, MASS. JULY 1950

PLATE 38

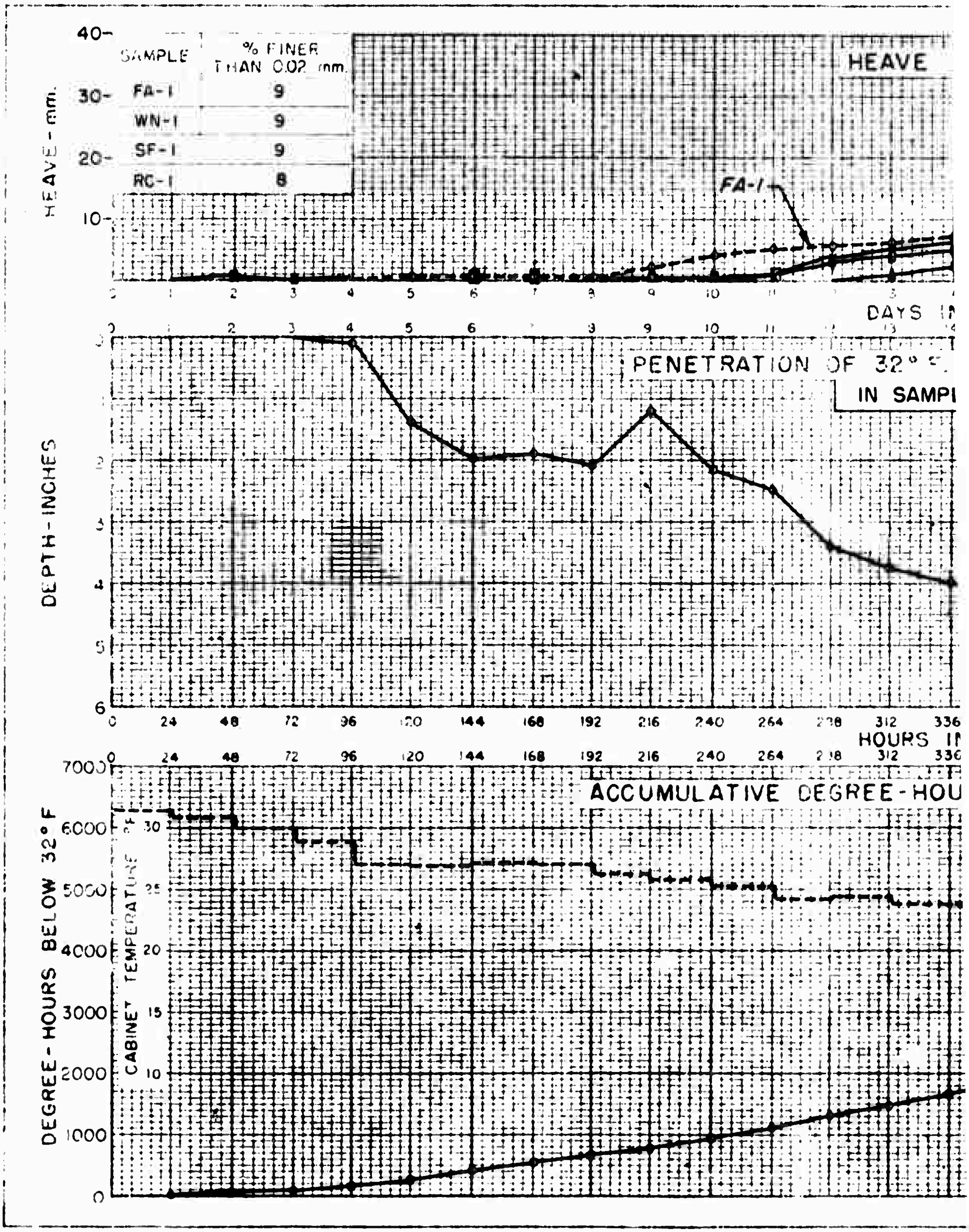

HEAVE V
SAMPLE
% FINER THAN 0.02 mm.
LA-1 24
LA-2 31
CA-2 18
CA-3 15
HEAVE - mm.
LA-2
DAYS IN
PENETRATION OF 32° F. T
IN SAMPL
DEPTH - INCHES
HOURS IN
ACCUMULATIVE DEGREE - HOUR
DEGREE - HOURS BELOW 32° F
CABINET TEMPERATURE - °F



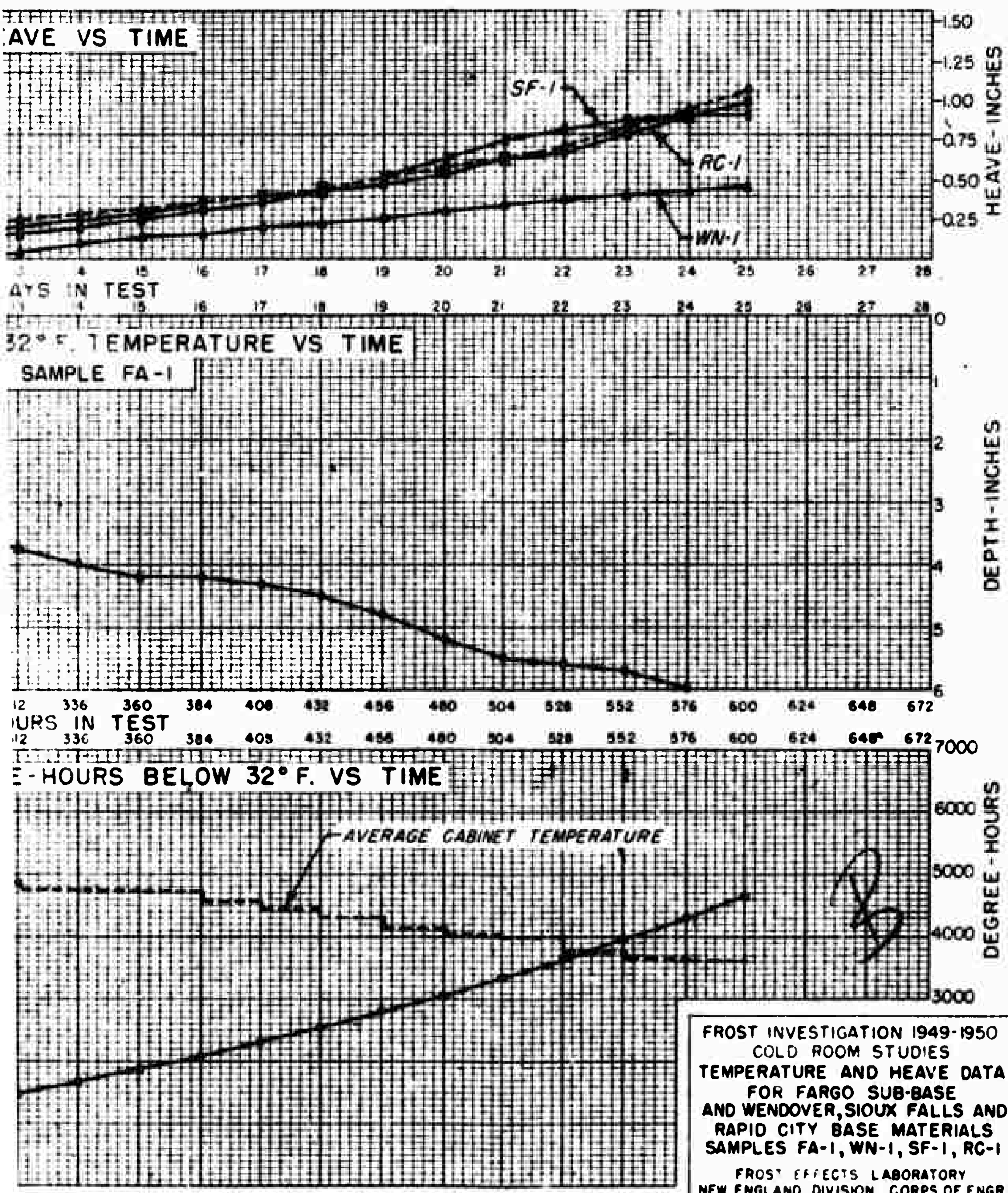
FROST INVESTIGATION 1949-1950
COLD ROOM STUDIES

TEMPERATURE AND HEAVE DATA FOR TYPICAL LOWRY AIRFIELD SUBGRADES AND CASPER AIRFIELD BASE AND SUBGRADE SAMPLES LA-1, LA-2, CA-2, CA-3

FROST EFFECTS LABORATORY
NEW ENGLAND DIVISION CORPS OF ENGR.
BOSTON, MASS. JULY 1950



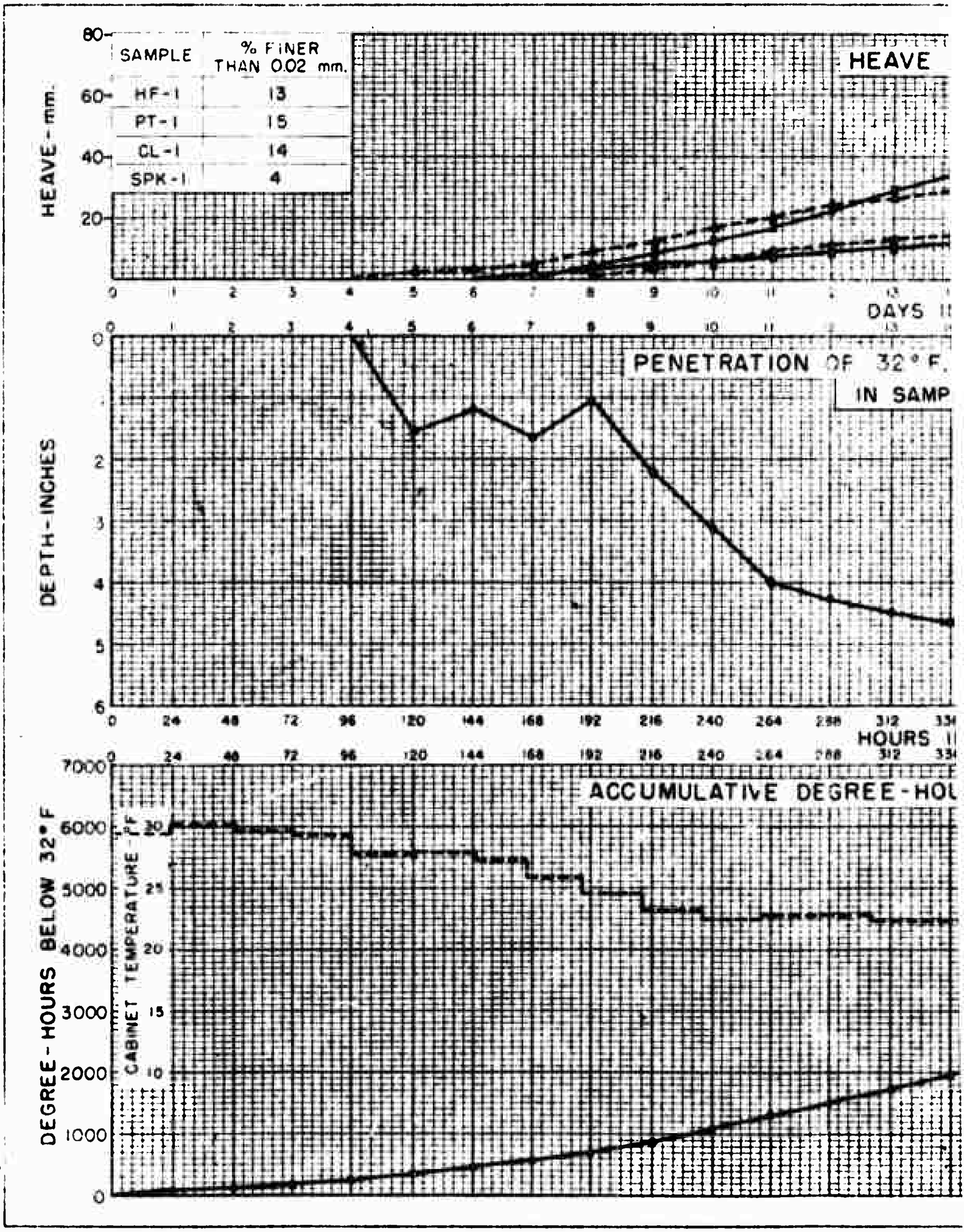
SAMPLE
% FINER THAN 0.02 mm.
FA-1 9
WN-1 9
SF-1 9
RC-1 8
HEAVE
FA-1
HEAVE - mm.
DAYS IN
PENETRATION OF 32° F
IN SAMPL
DEPTH - INCHES
HOURS IN
ACCUMULATIVE DEGREE-HOU
DEGREE-HOURS BELOW 32° F
CABINET TEMPERATURE °F

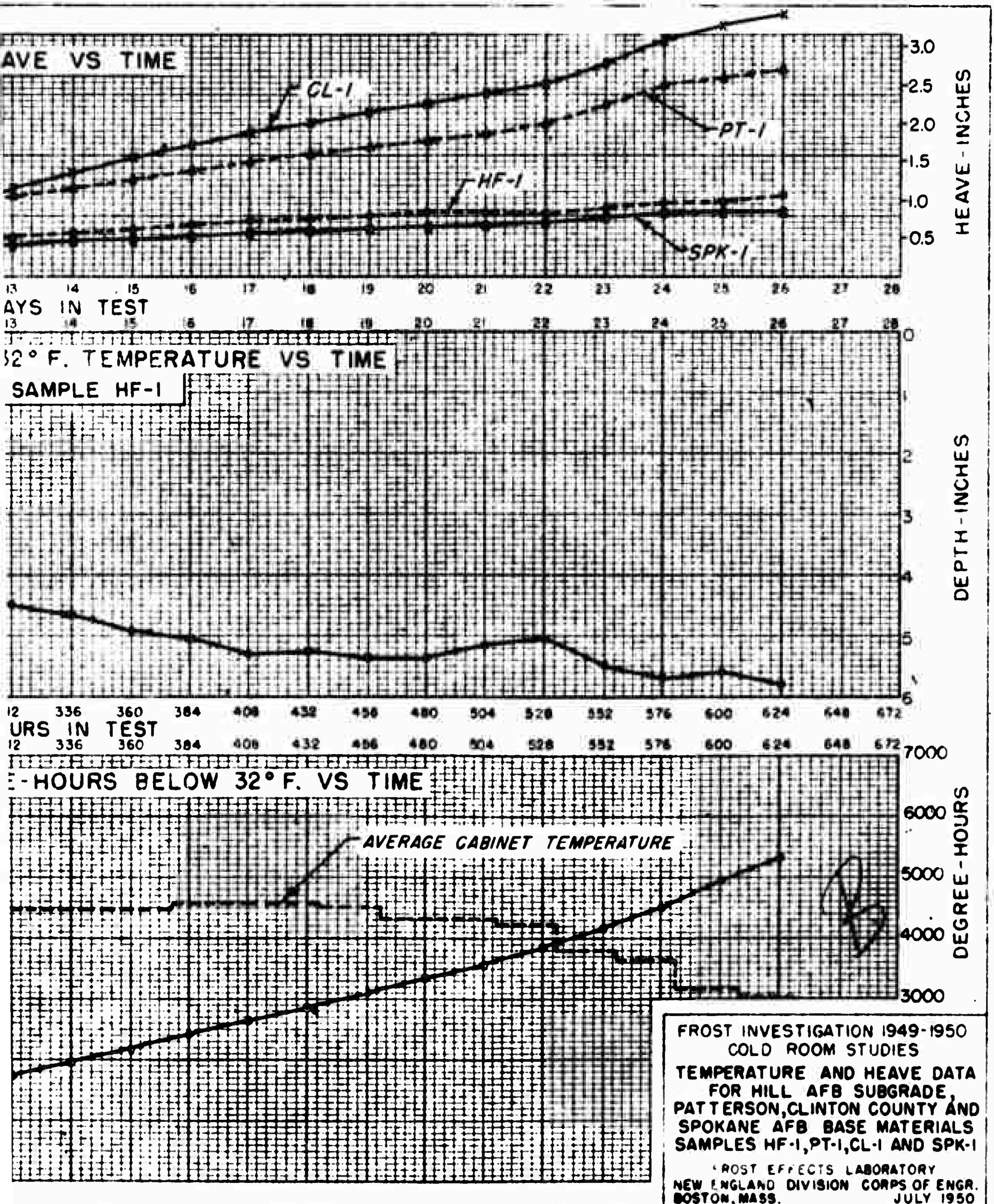


FROST INVESTIGATION 1949-1950
COLD ROOM STUDIES
TEMPERATURE AND HEAVE DATA
FOR FARGO SUB-BASE
AND WENDOVER, SIOUX FALLS AND
RAPID CITY BASE MATERIALS
SAMPLES FA-1, WN-1, SF-1, RC-1

FROST EFFECTS LABORATORY
NEW ENGLAND DIVISION CORPS OF ENGR.
BOSTON, MASS. JULY 1950

PLATE 40

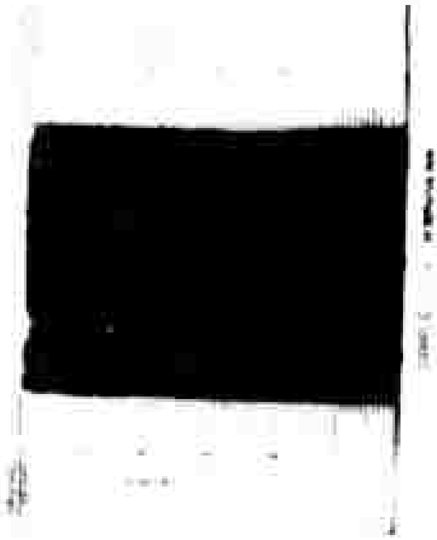

SAMPLE
% FINER THAN 0.02 mm.
HF-1 13
PT-1 15
CL-1 14
SPK-1 4
HEAVE
HEAVE - mm.
DAYS
PENETRATION OF 32° F.
IN SAMP
DEPTH-INCHES
HOURS
ACCUMULATIVE DEGREE-HOU
DEGREE - HOURS BELOW 32° F
CABINET TEMPERATURE - °F



AVE VS TIME
CL-1
PT-1
HF-1
SPK-1
HEAVE - INCHES
AYS IN TEST
32° F. TEMPERATURE VS TIME
SAMPLE HF-1
DEPTH - INCHES
URS IN TEST
-HOURS BELOW 32° F. VS TIME
AVERAGE CABINET TEMPERATURE
DEGREE - HOURS
FROST INVESTIGATION 1949-1950
COLD ROOM STUDIES
TEMPERATURE AND HEAVE DATA
FOR HILL AFB SUBGRADE,
PATTERSON, CLINTON COUNTY AND
SPOKANE AFB BASE MATERIALS
SAMPLES HF-1, PT-1, CL-1 AND SPK-1
FROST EFFECTS LABORATORY
NEW ENGLAND DIVISION CORPS OF ENGR.
BOSTON, MASS. JULY 1950

PLATE 41

PLATE 42



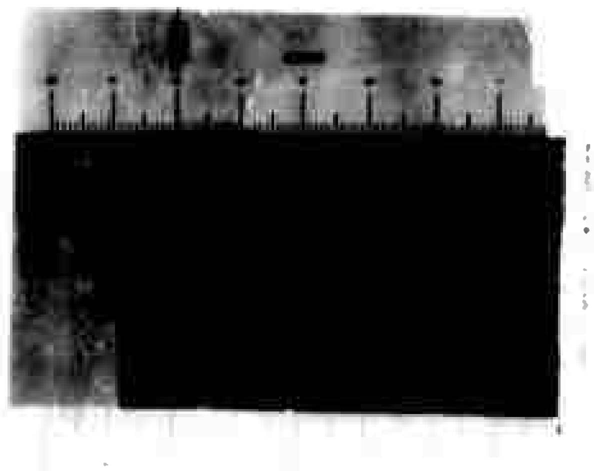
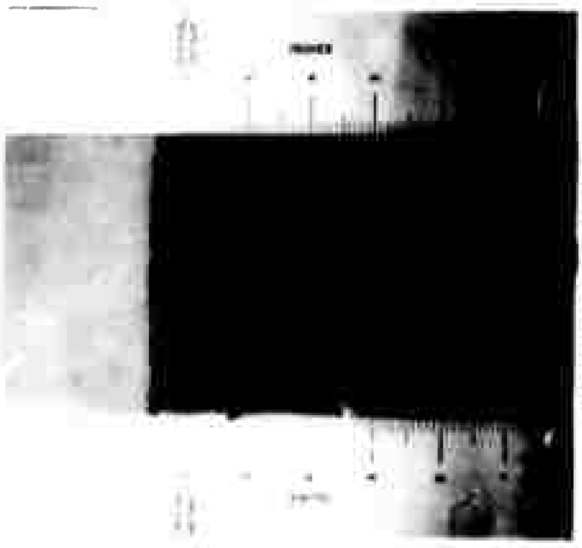


PLATE 43



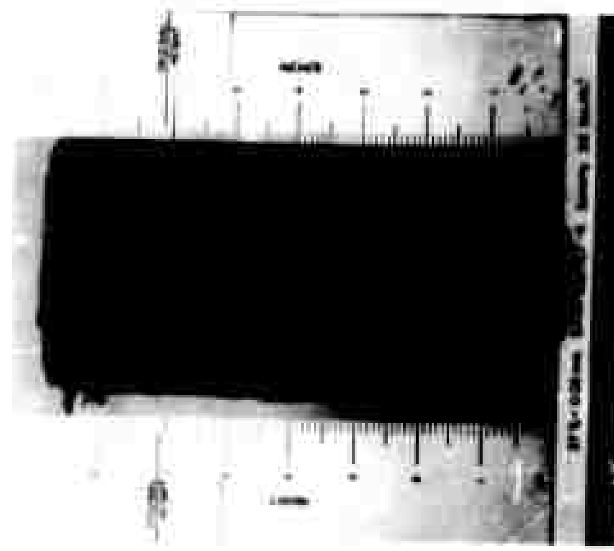
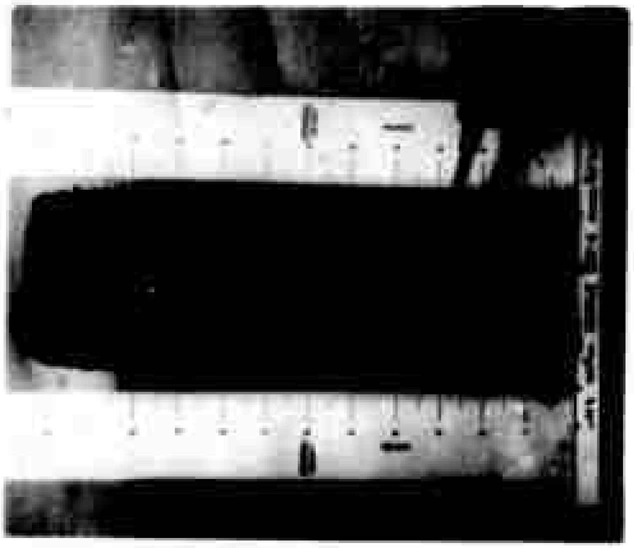
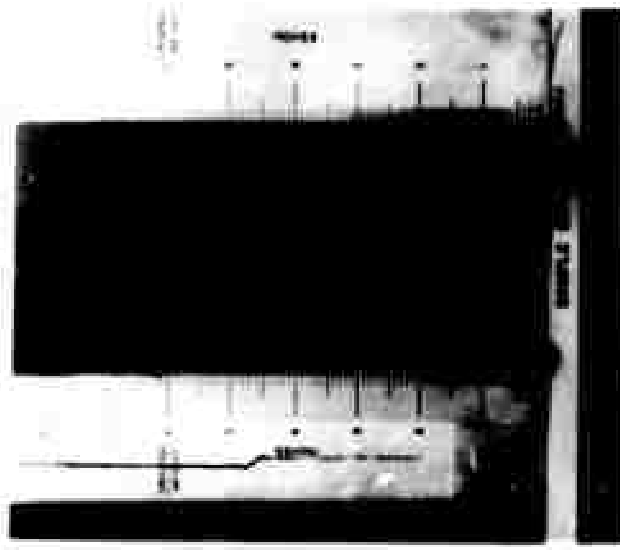


PLATE 44





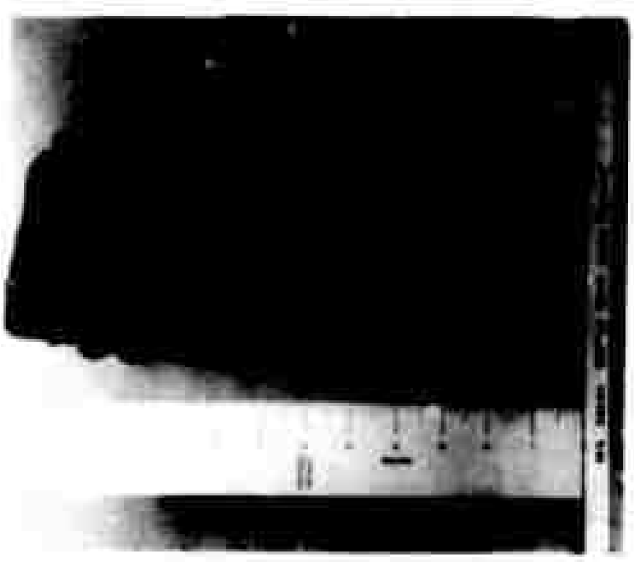
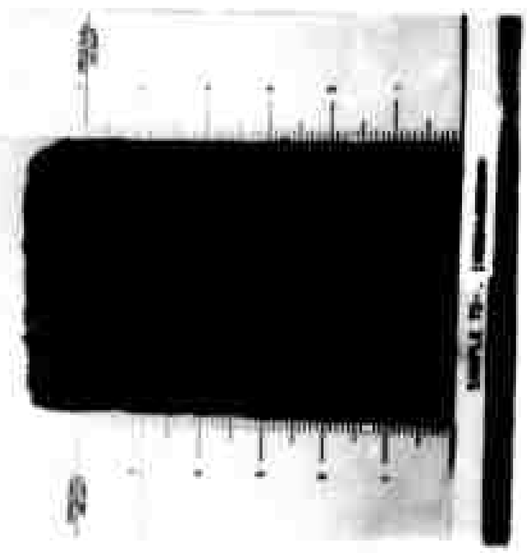
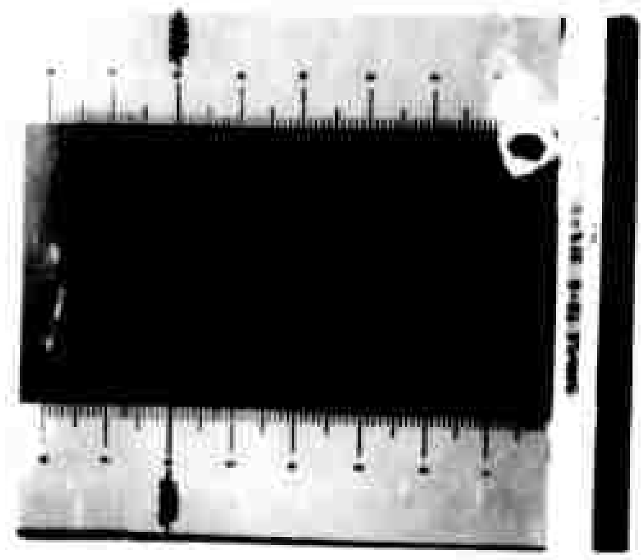


PLATE 45





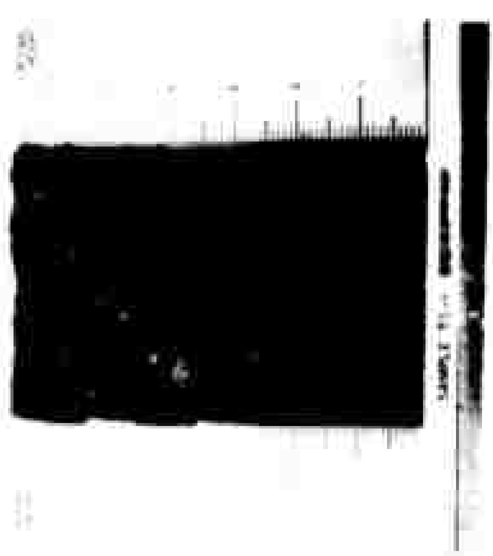


PLATE 46

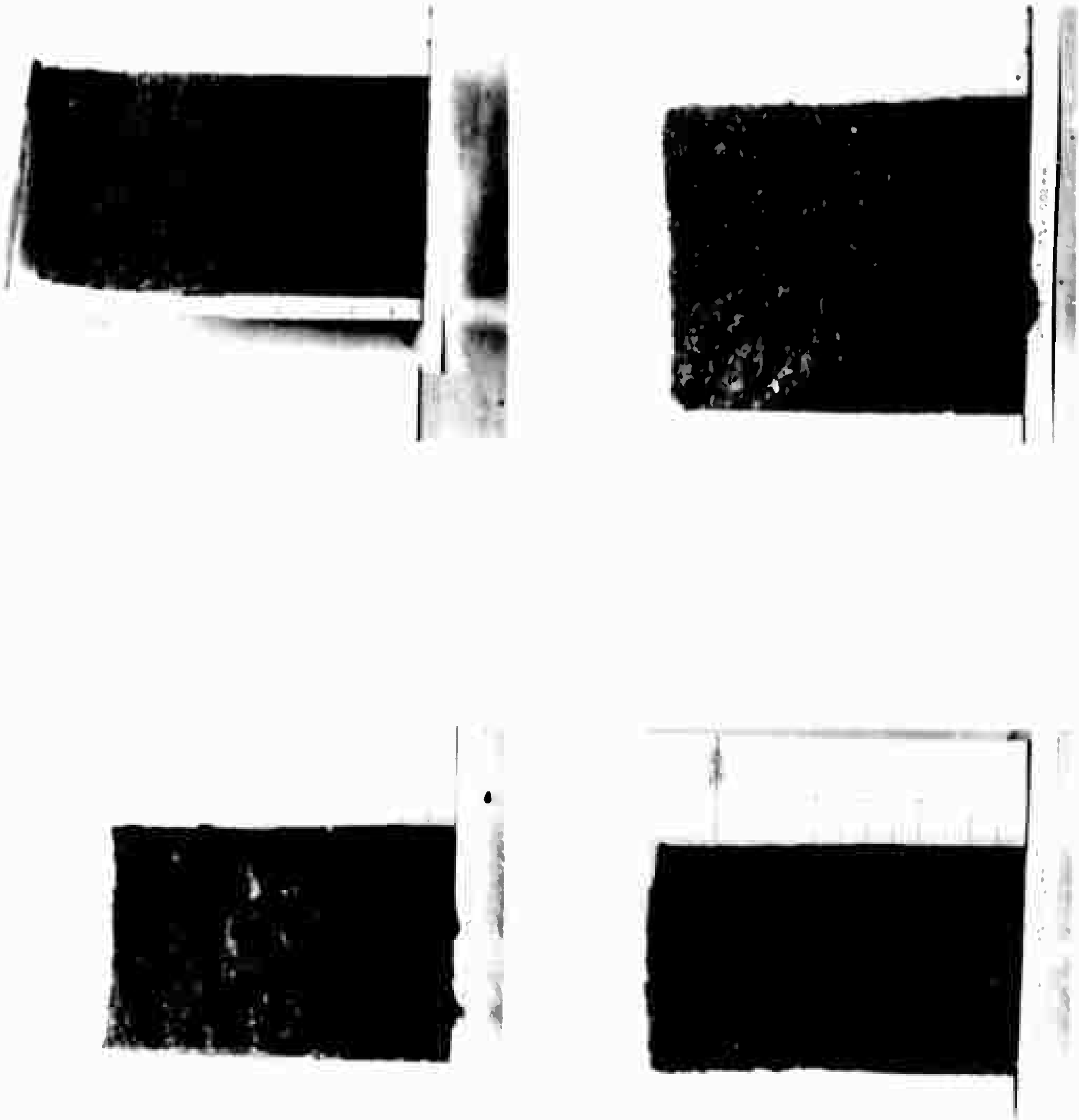


PLATE 47

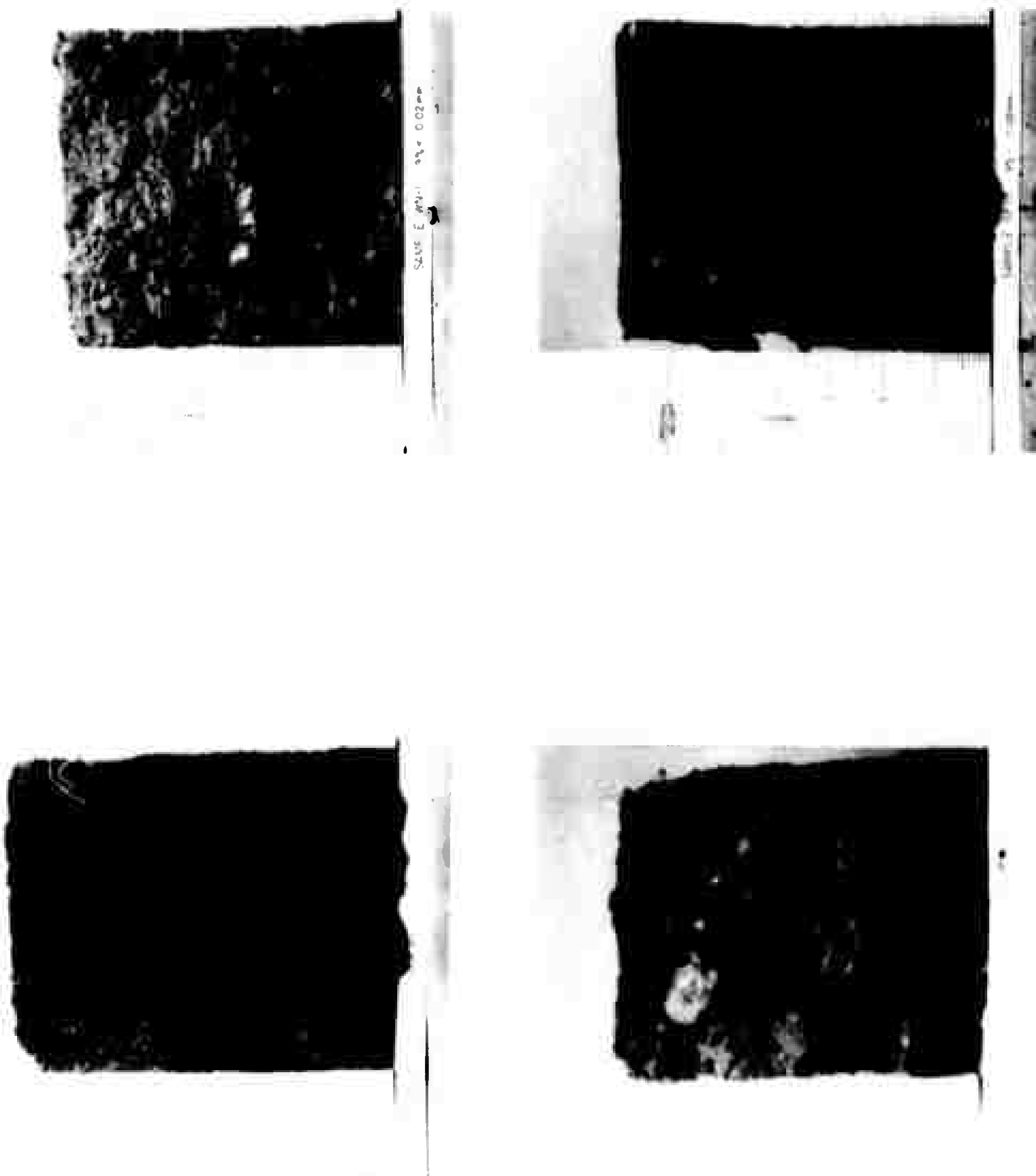


PLATE 48

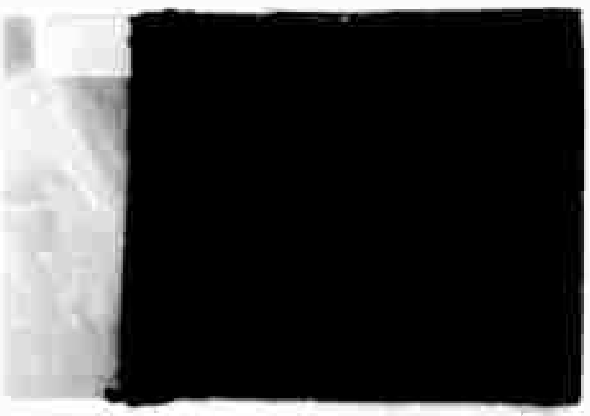


PLATE 49

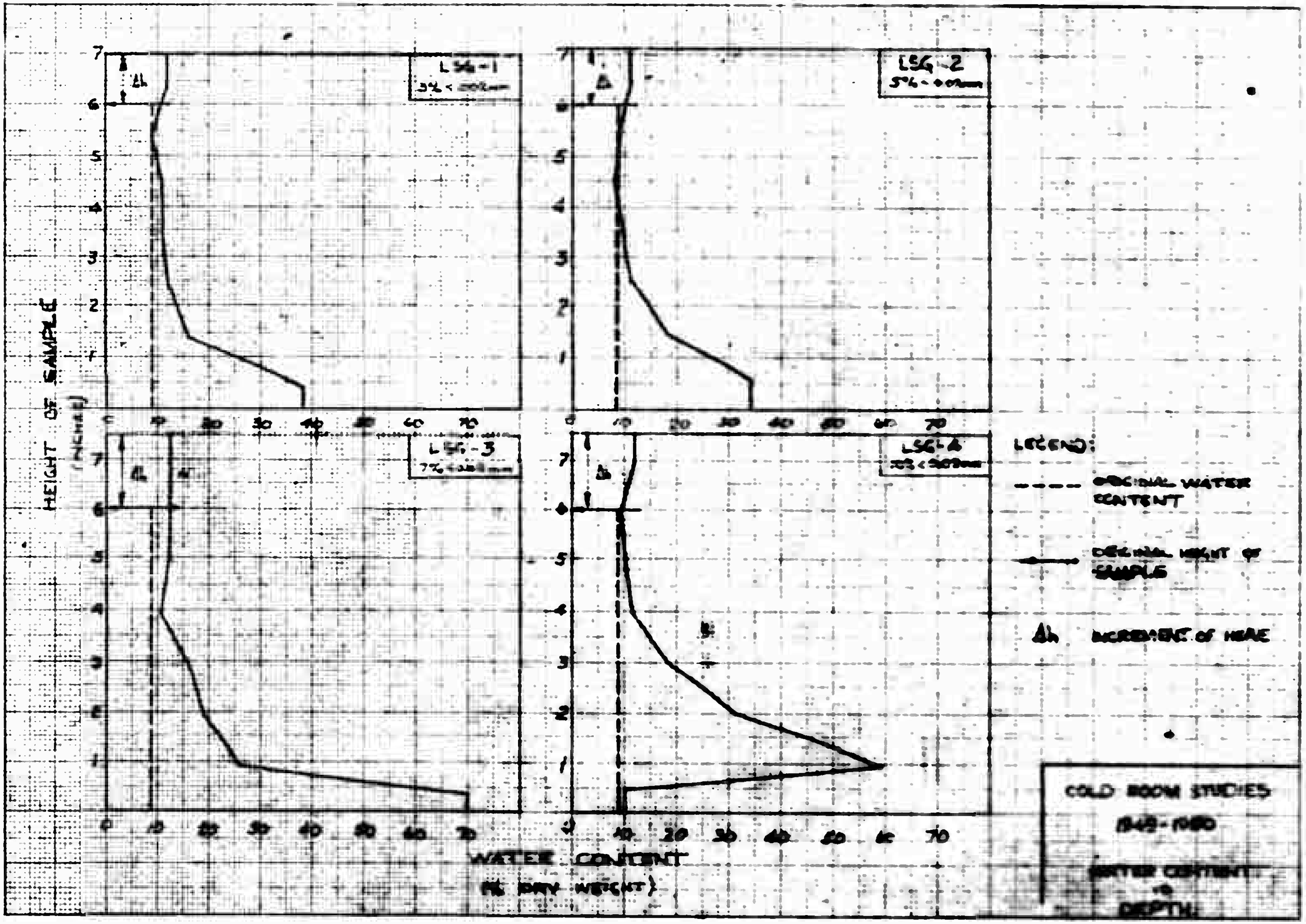
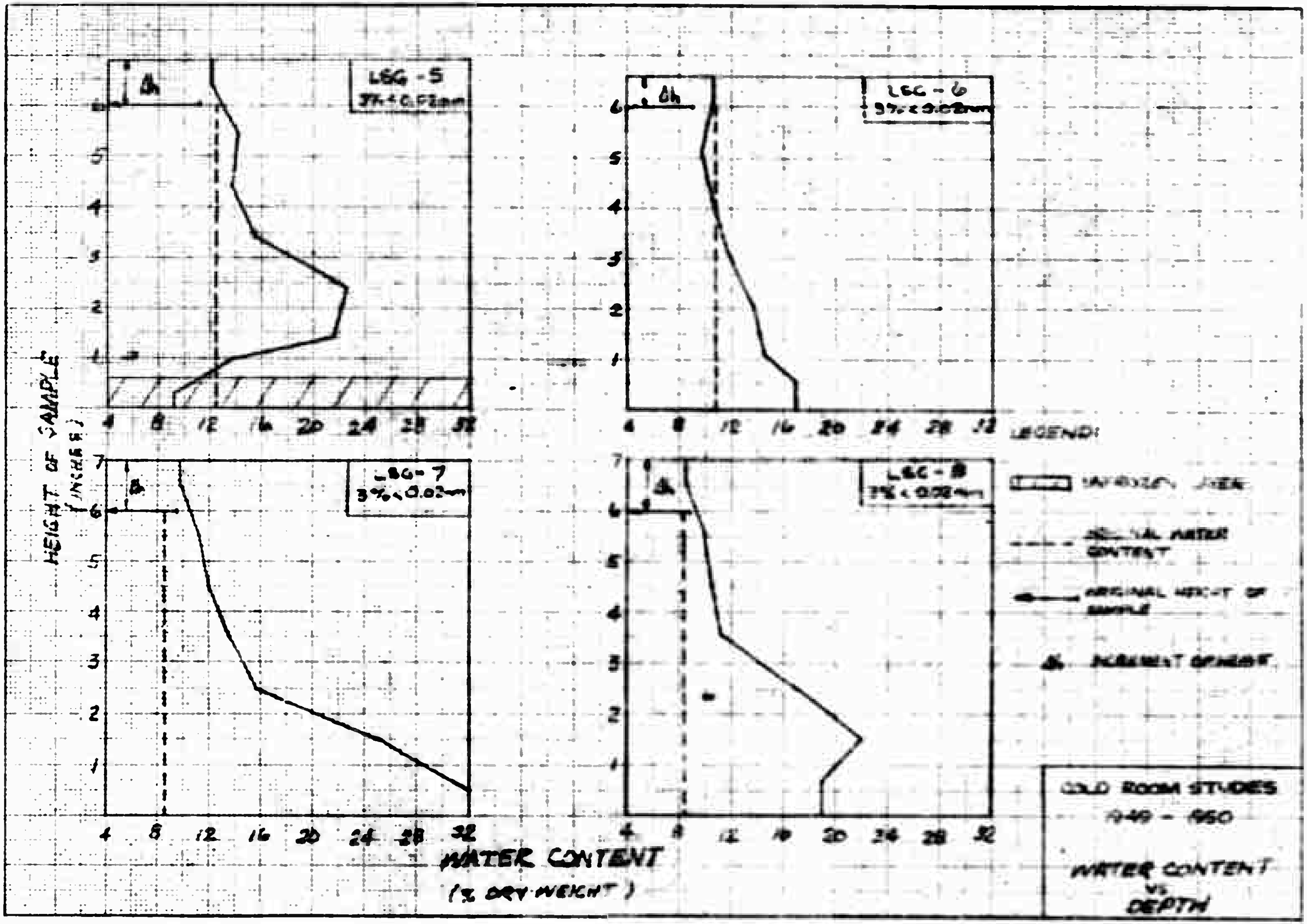
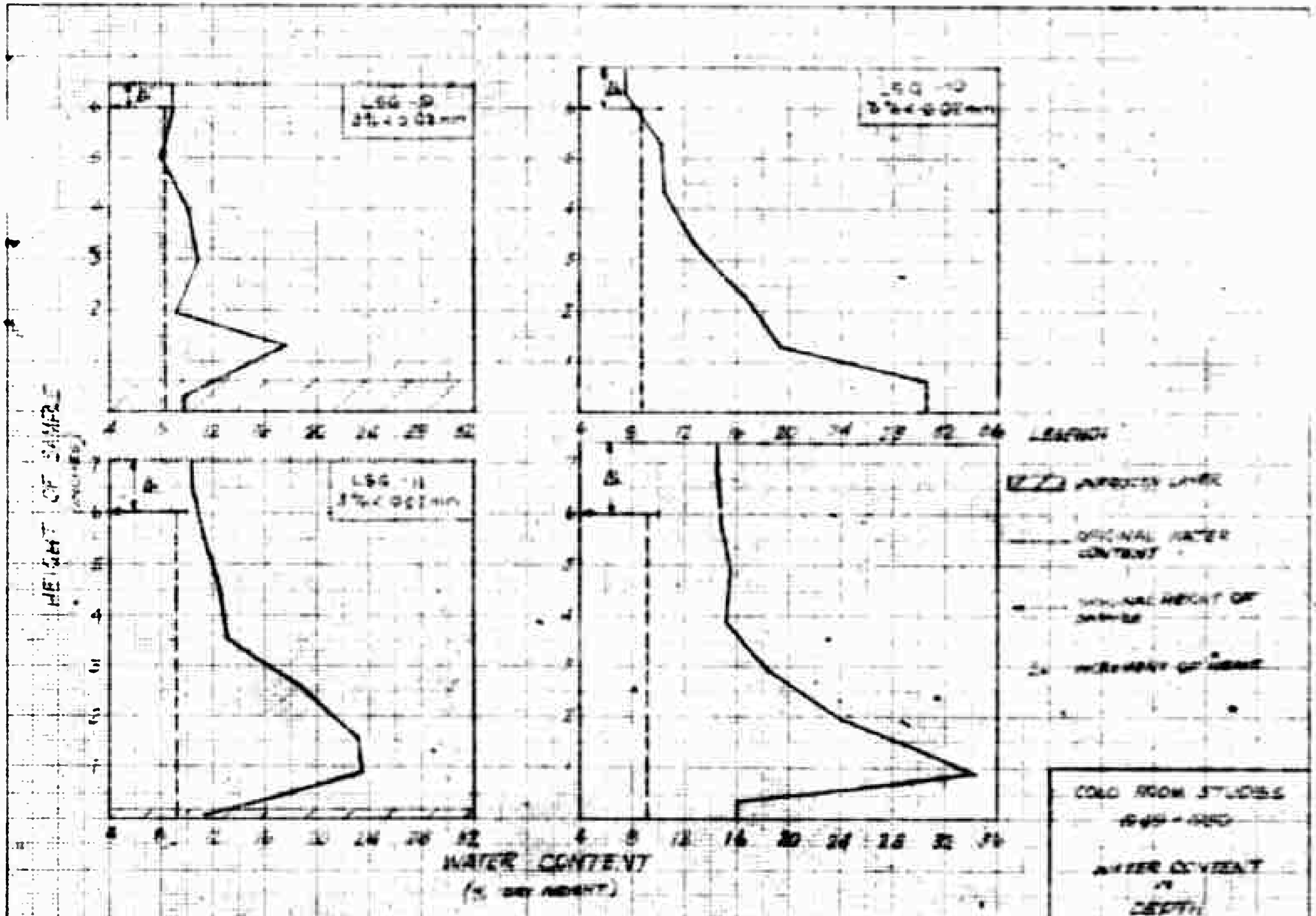
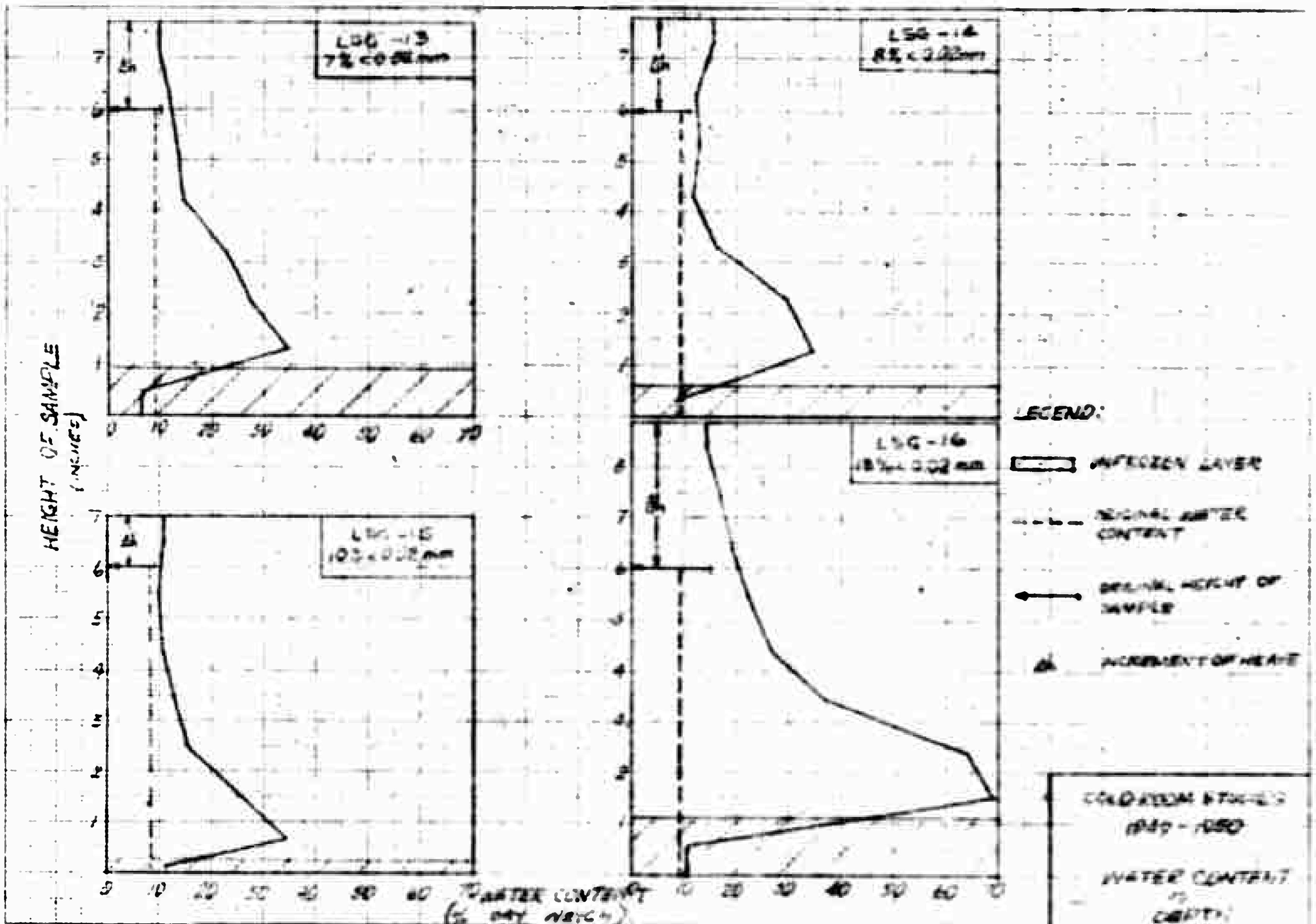

LSG-1
LSG-2
LSG-3
LSG-4
HEIGHT OF SAMPLE (INCHES)
WATER CONTENT (% DRY WEIGHT)
LEGEND:
ORIGINAL WATER CONTENT
ORIGINAL HEIGHT OF SAMPLE
Δh INCREMENT OF HEAVE
COLD ROOM STUDIES
WATER CONTENT vs DEPTH

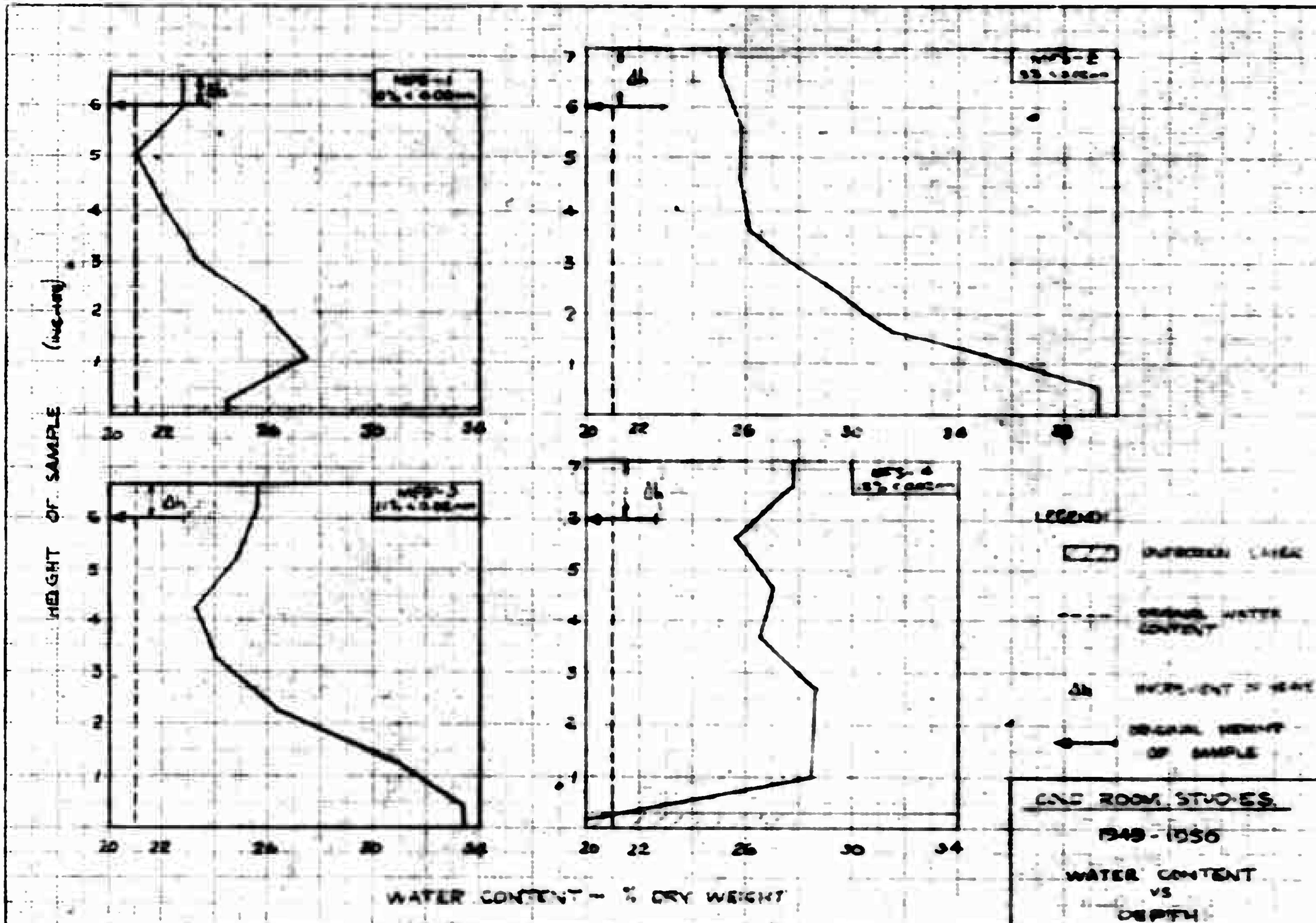
PLATE 30



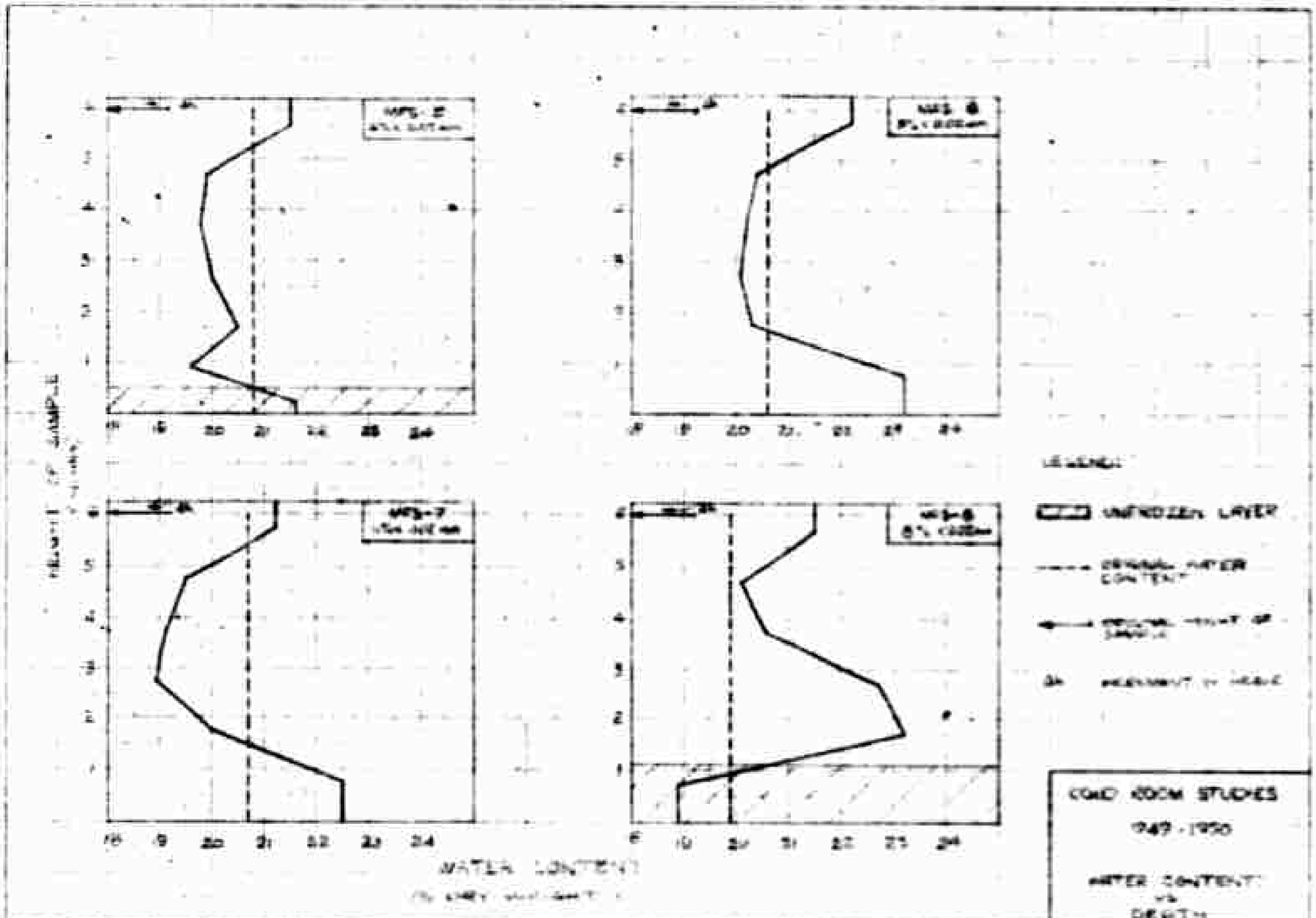
LSG - 5
3% < 0.02mm
LSG - 6
3% < 0.02mm
LSG - 7
3% < 0.02mm
LSG - 8
3% < 0.02mm
Δh
HEIGHT OF SAMPLE (INCHES)
WATER CONTENT (% DRY WEIGHT)
LEGEND:
ORIGINAL WATER CONTENT
ORIGINAL HEIGHT OF SAMPLE
COLD ROOM STUDIES
1949 - 1950
WATER CONTENT vs. DEPTH

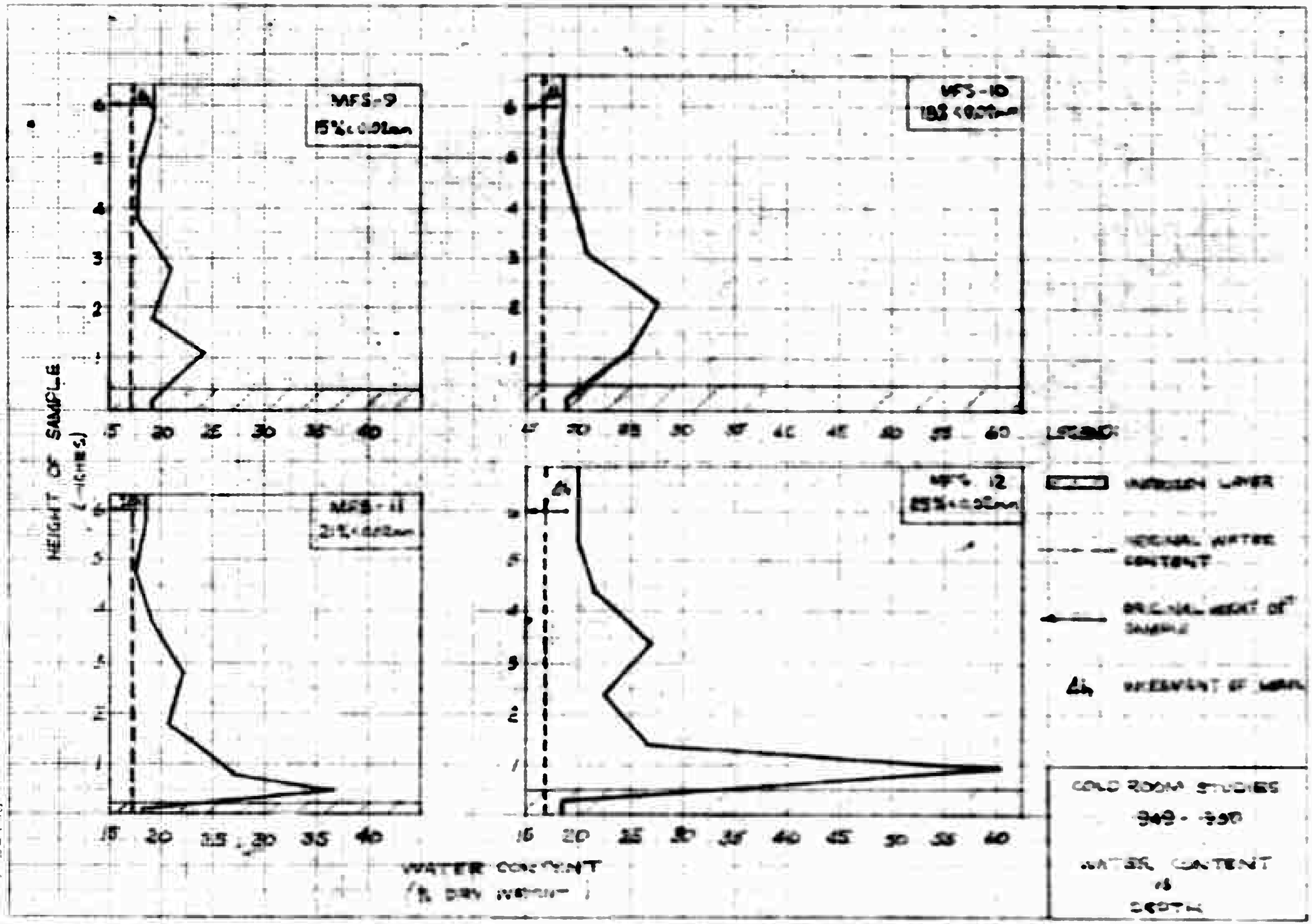

LSG-9
LSG-10
LSG-11
HEIGHT OF SAMPLE
(INCHES)
WATER CONTENT
(% DRY WEIGHT)
LEGEND
ORIGINAL WATER CONTENT
ORIGINAL HEIGHT OF SAMPLE
COLD ROOM STUDIES
1949-1950
WATER CONTENT
vs
DEPTH

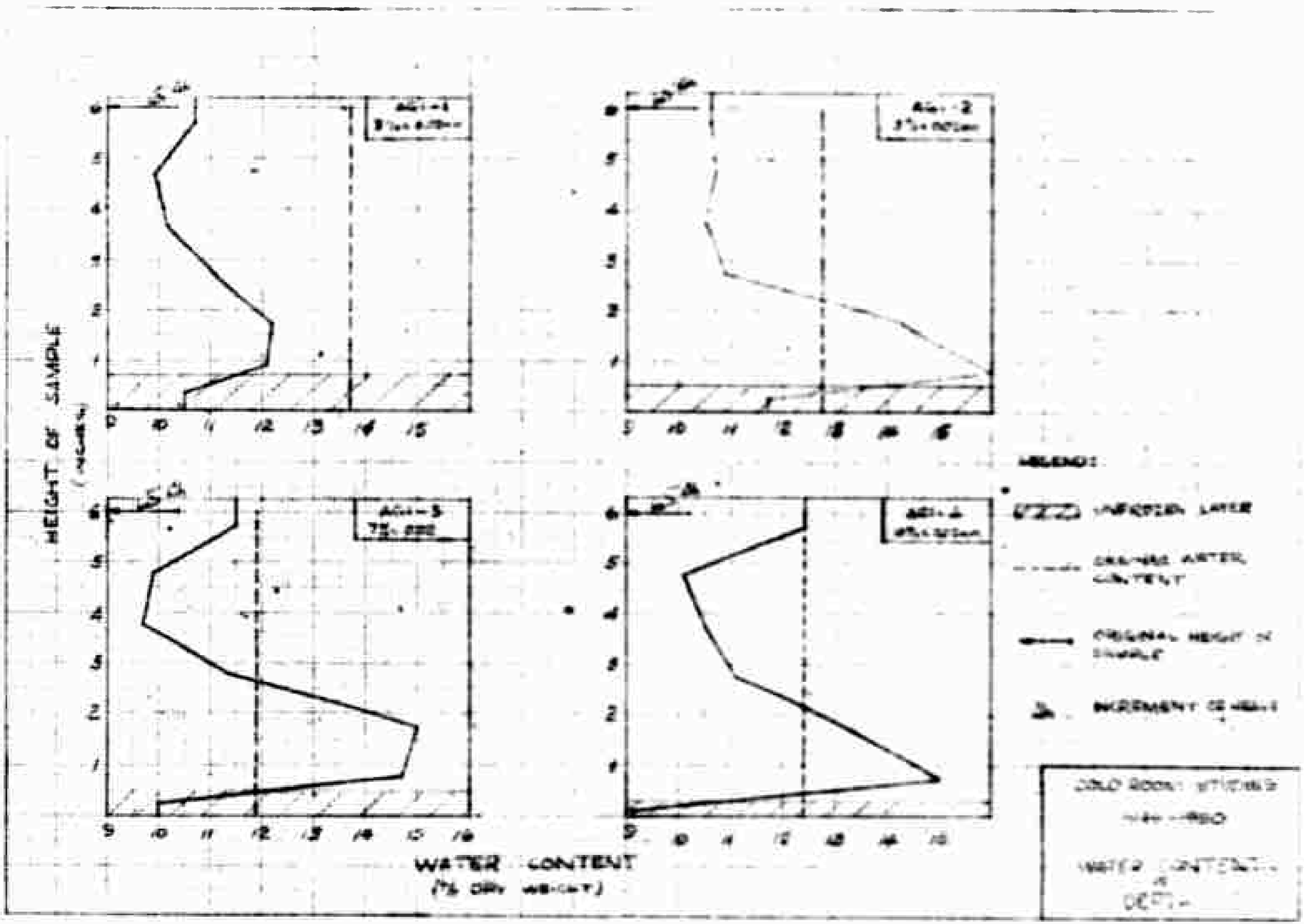

LSG-13
7% < 0.02 mm
LSG-14
8% < 0.02 mm
LSG-15
10% < 0.02 mm
LSG-16
18% < 0.02 mm
HEIGHT OF SAMPLE (INCHES)
WATER CONTENT (% DRY WEIGHT)
LEGEND:
UNFROZEN LAYER
ORIGINAL WATER CONTENT
ORIGINAL HEIGHT OF SAMPLE
INCREMENT OF HEAVE
COLD ROOM STUDIES
1949 - 1950
WATER CONTENT vs DEPTH

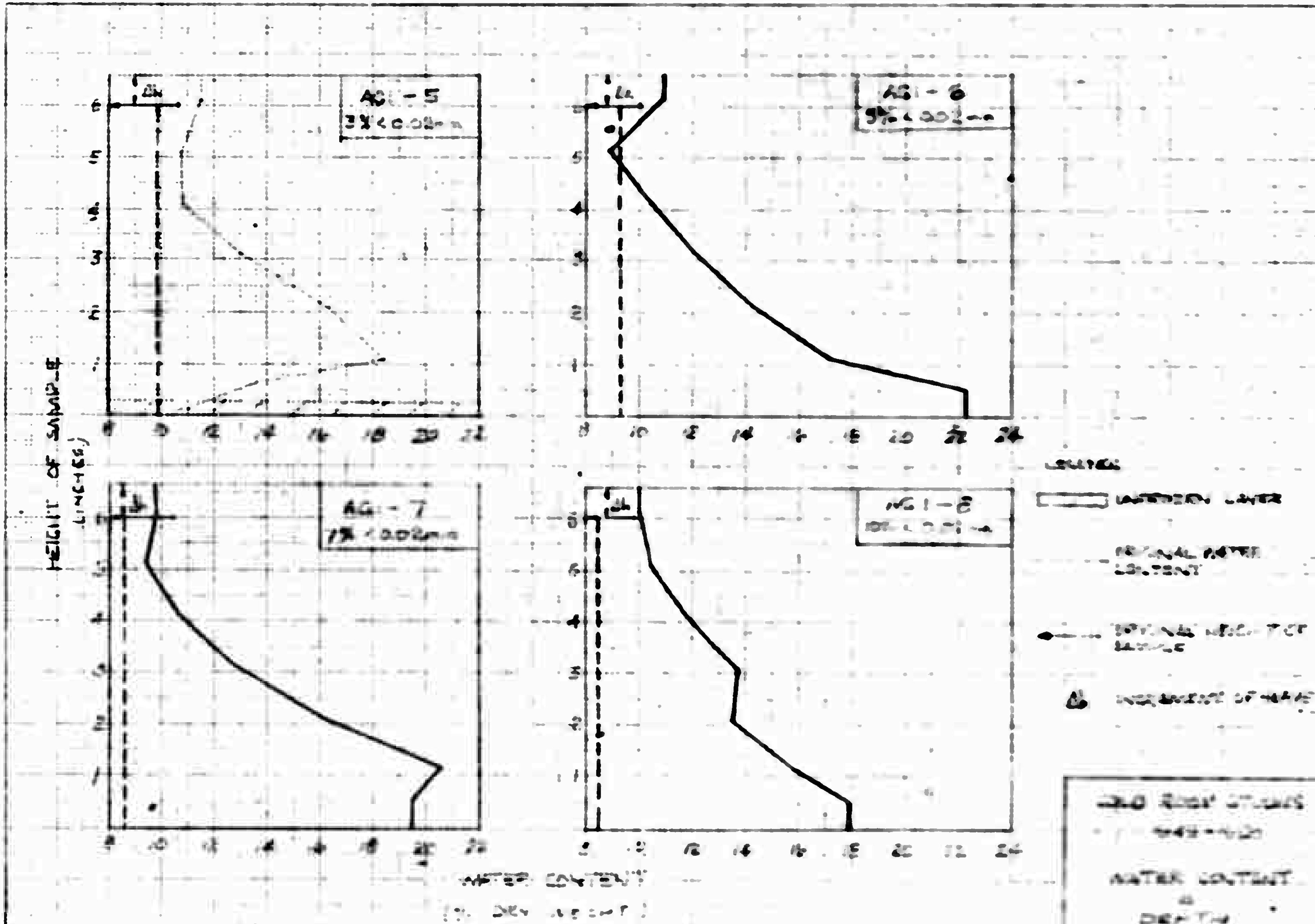


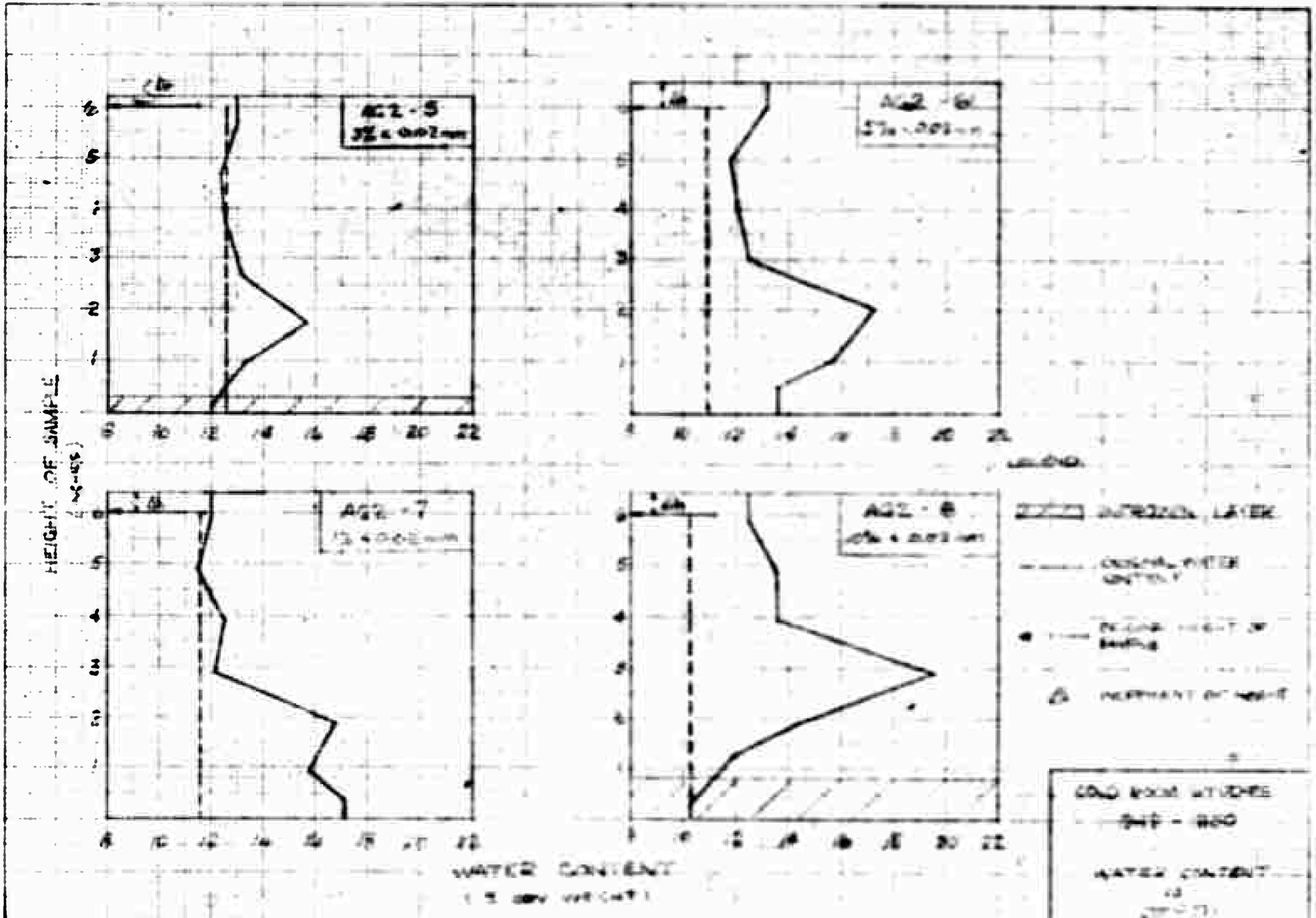
HEIGHT OF SAMPLE (inches)
WATER CONTENT – % DRY WEIGHT
LEGEND
Δh
ORIGINAL HEIGHT OF SAMPLE
COLD ROOM STUDIES
1949 - 1956
WATER CONTENT
VS
DEPTH

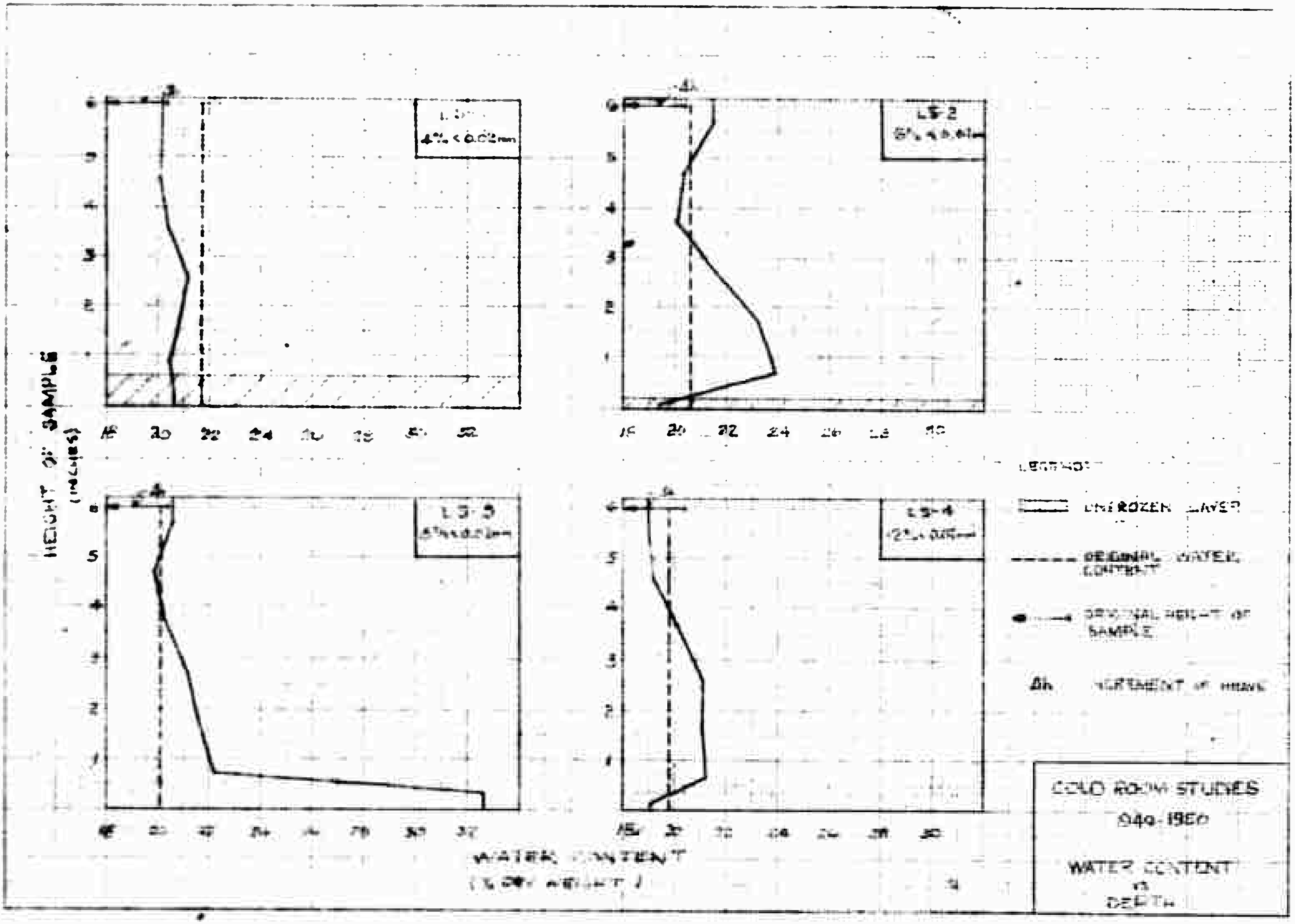

COLD ROOM STUDIES
1949-1950
WATER CONTENT
VS
DEPTH
LEGEND:
UNFROZEN LAYER
ORIGINAL WATER CONTENT
ORIGINAL HEIGHT OF SAMPLE
WATER CONTENT
HEIGHT OF SAMPLE

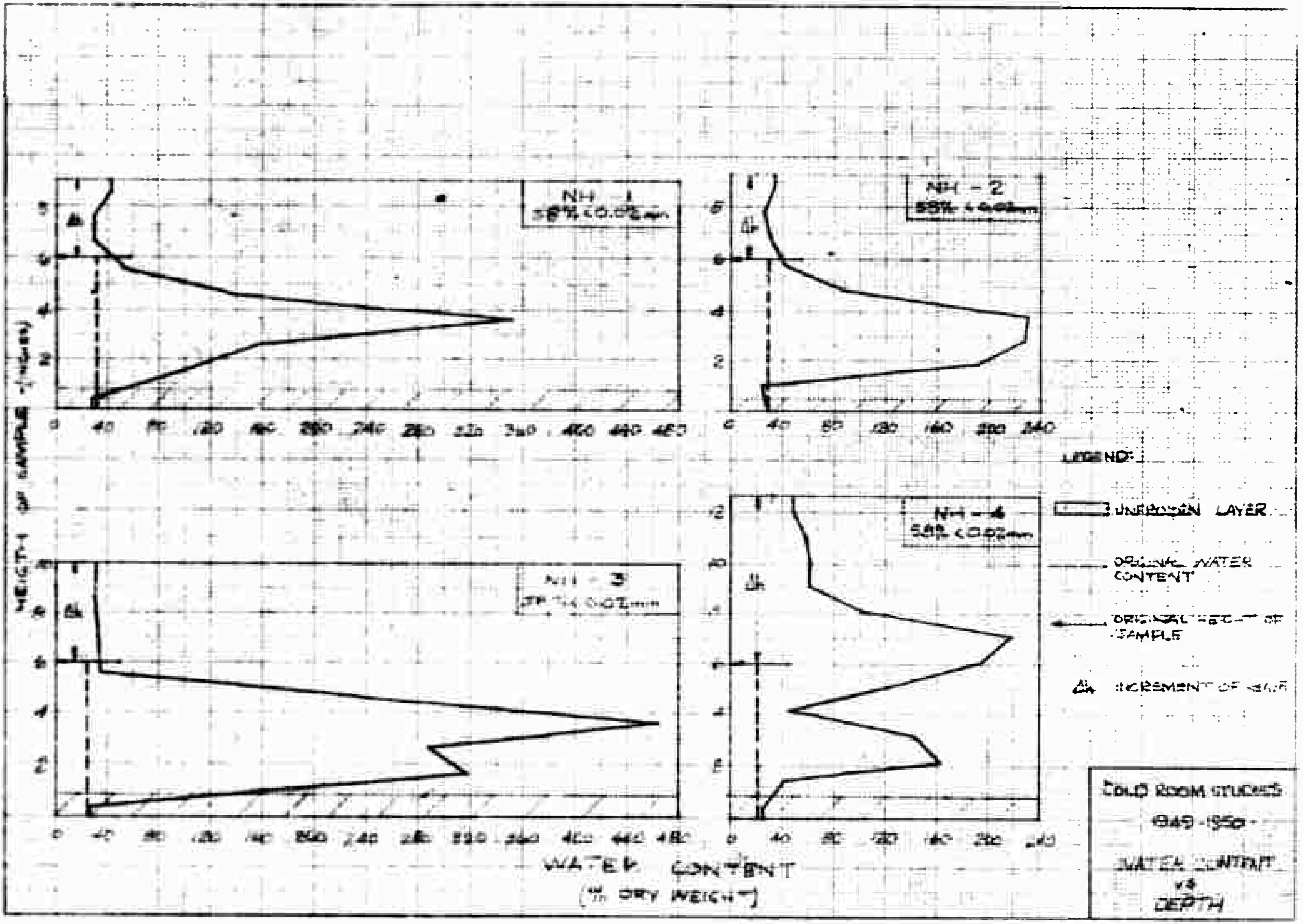

MFS-9
MFS-10
MFS-11
MFS-12
HEIGHT OF SAMPLE
WATER CONTENT
LEGEND
ORIGINAL WATER CONTENT
COLD ROOM STUDIES
WATER CONTENT
DEPTH

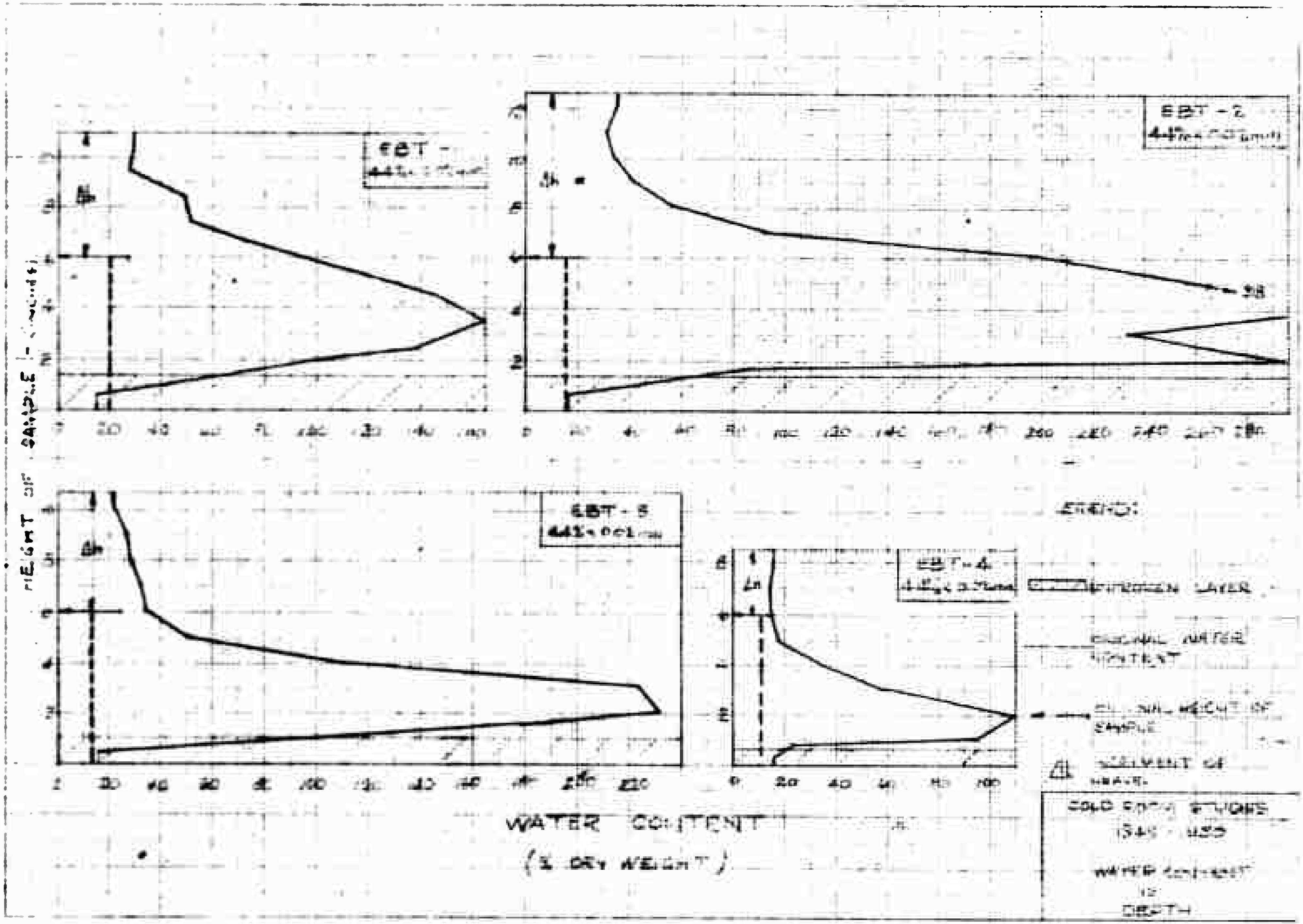

HEIGHT OF SAMPLE
WATER CONTENT
LEGEND:
UNFROZEN LAYER
ORIGINAL HEIGHT OF SAMPLE

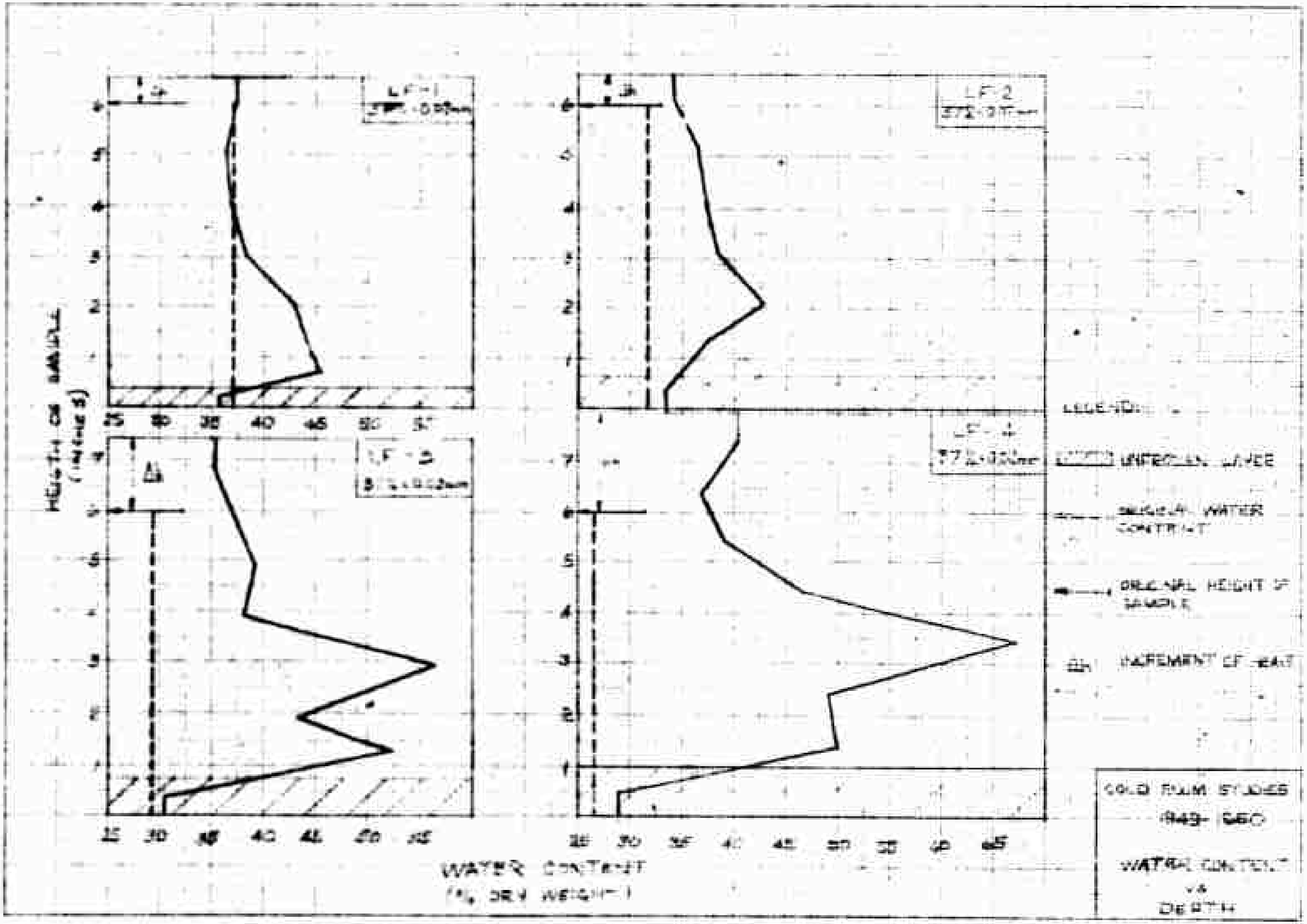

AG-5
3% < 0.002mm
AG-6
AG-7
7% < 0.002mm
HEIGHT OF SAMPLE
(INCHES)
WATER CONTENT
(% DRY WEIGHT)
WATER CONTENT
vs
DEPTH

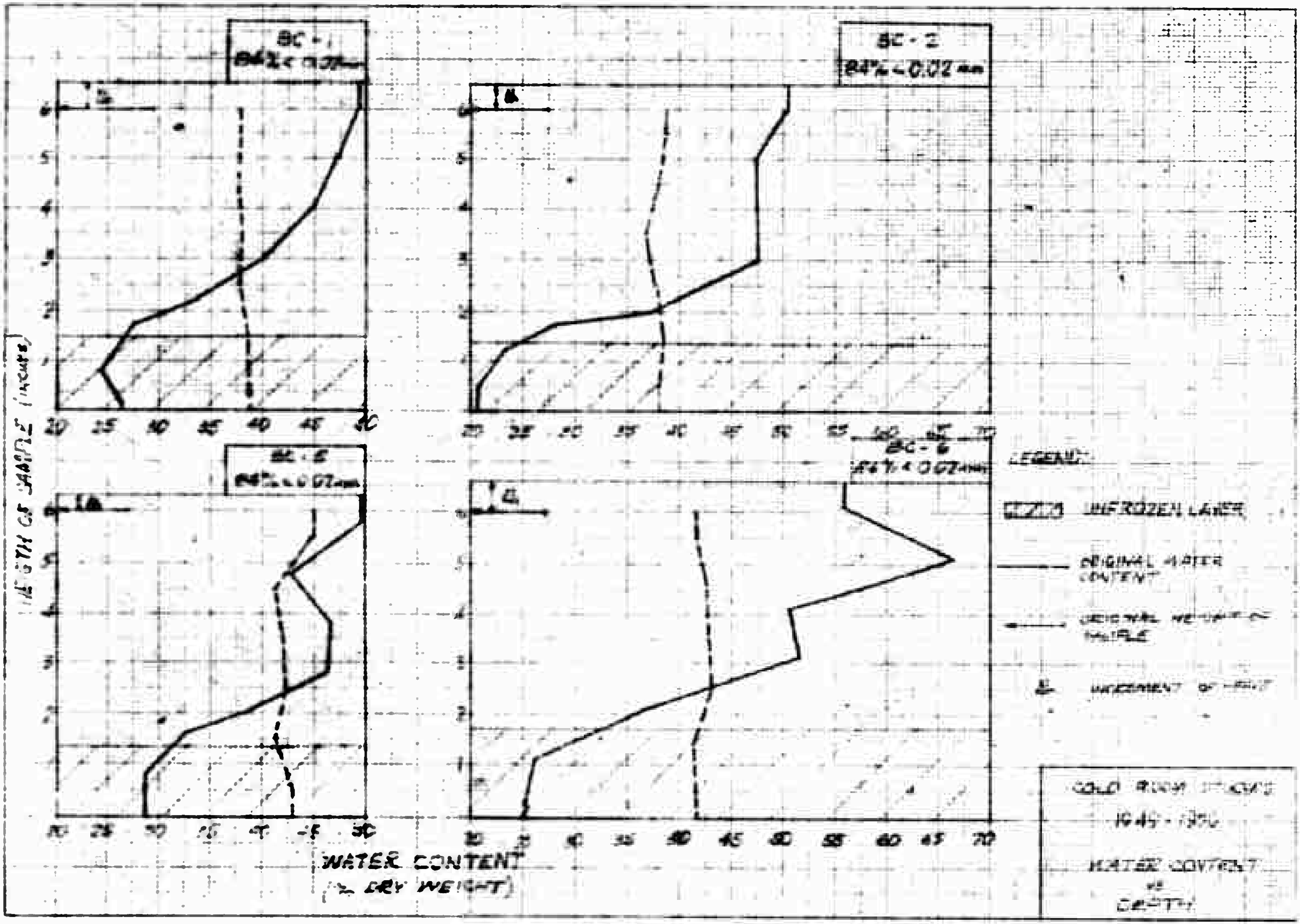

HEIGHT OF SAMPLE
WATER CONTENT
LEGEND

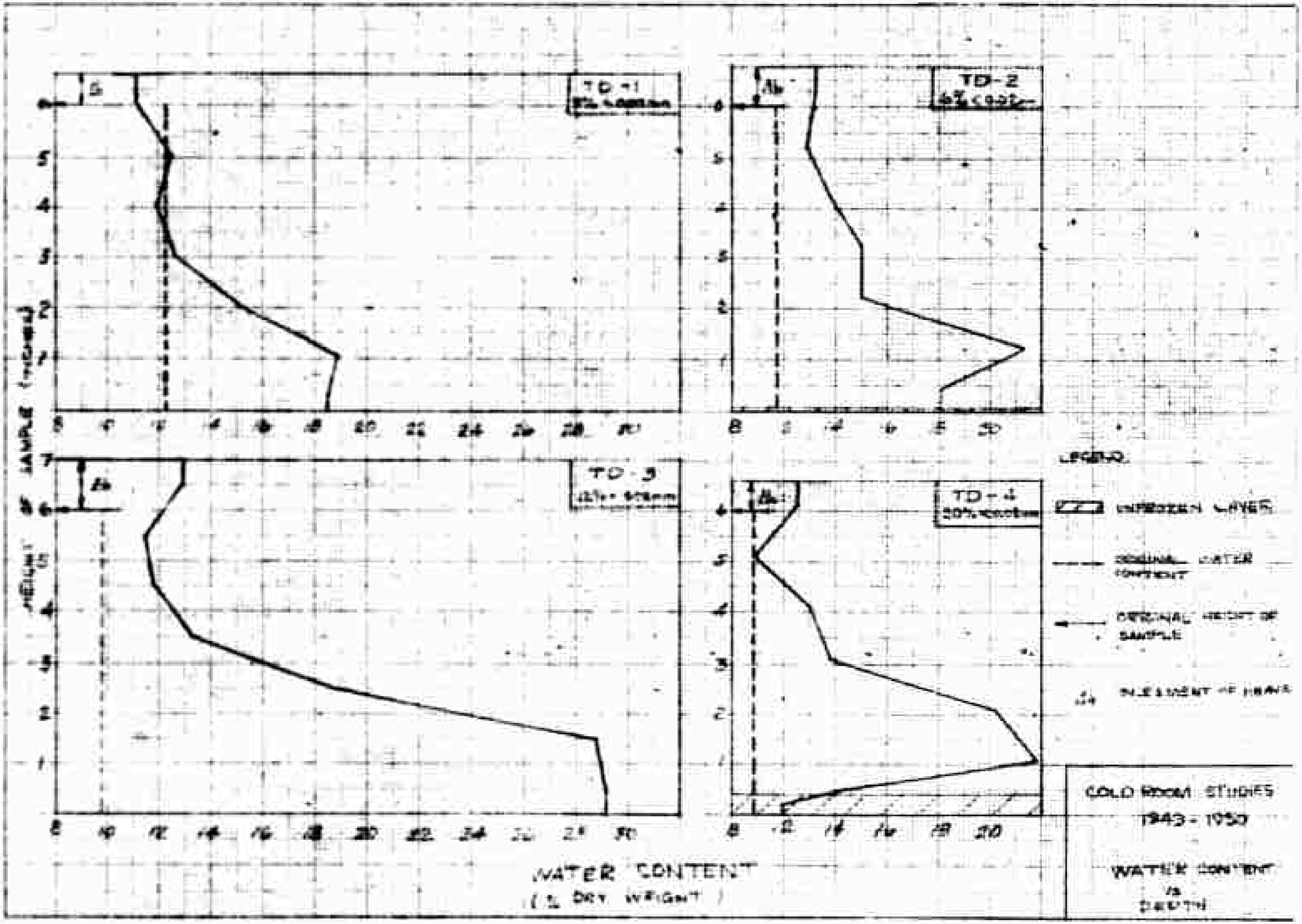

LS-2
4% < 0.02mm
LEGEND
UNFROZEN LAYER
ORIGINAL WATER CONTENT
ORIGINAL HEIGHT OF SAMPLE
Δh INCREMENT OF HEAVE
HEIGHT OF SAMPLE (INCHES)
WATER CONTENT (% DRY WEIGHT)
COLD ROOM STUDIES
WATER CONTENT vs DEPTH


NH - 1
58% < 0.02 mm
NH - 2
58% < 0.02 mm
NH - 3
NH - 4
58% < 0.02 mm
HEIGHT OF SAMPLE - (INCHES)
WATER CONTENT
(% DRY WEIGHT)
LEGEND:
UNFROZEN LAYER
ORIGINAL WATER CONTENT
ORIGINAL HEIGHT OF SAMPLE
INCREMENT OF HEAVE
COLD ROOM STUDIES
1949 - 1950
WATER CONTENT
VS
DEPTH

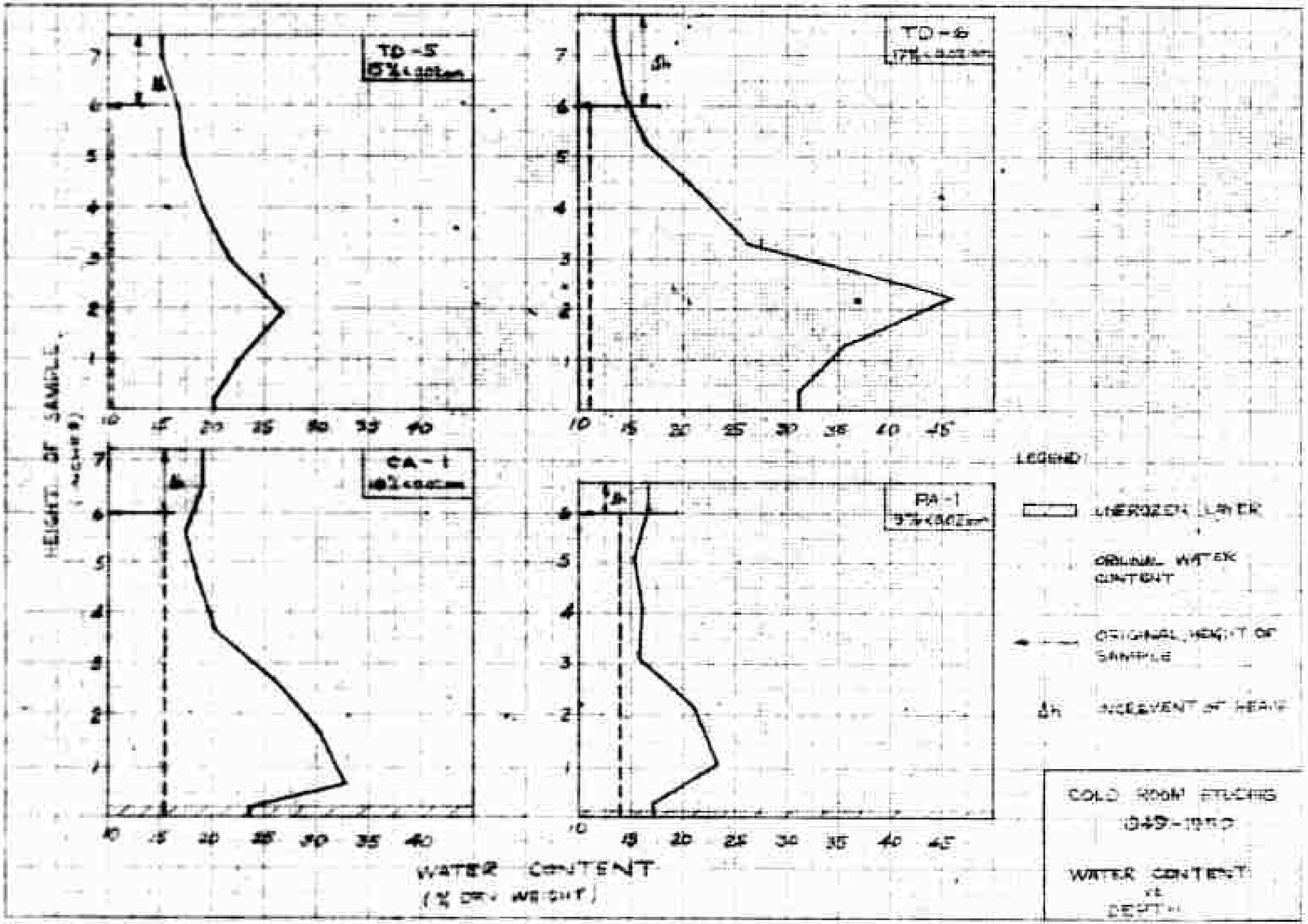

EBT - 2
EBT - 5
EBT - 4
LEGEND:
FROZEN LAYER
ORIGINAL WATER CONTENT
SAMPLE
WATER CONTENT
(% DRY WEIGHT)
HEIGHT OF SAMPLE
COLD ROOM STUDIES
WATER CONTENT
DEPTH


COLD ROOM STUDIES
1949-1950
WATER CONTENT
VS
DEPTH
LEGEND:
UNFROZEN LAYER
ORIGINAL WATER CONTENT
ORIGINAL HEIGHT OF SAMPLE
INCREMENT OF HEAVE
LF-1
LF-2
LF-3
LF-4
HEIGHT OF SAMPLE
(INCHES)
WATER CONTENT
(% DRY WEIGHT)

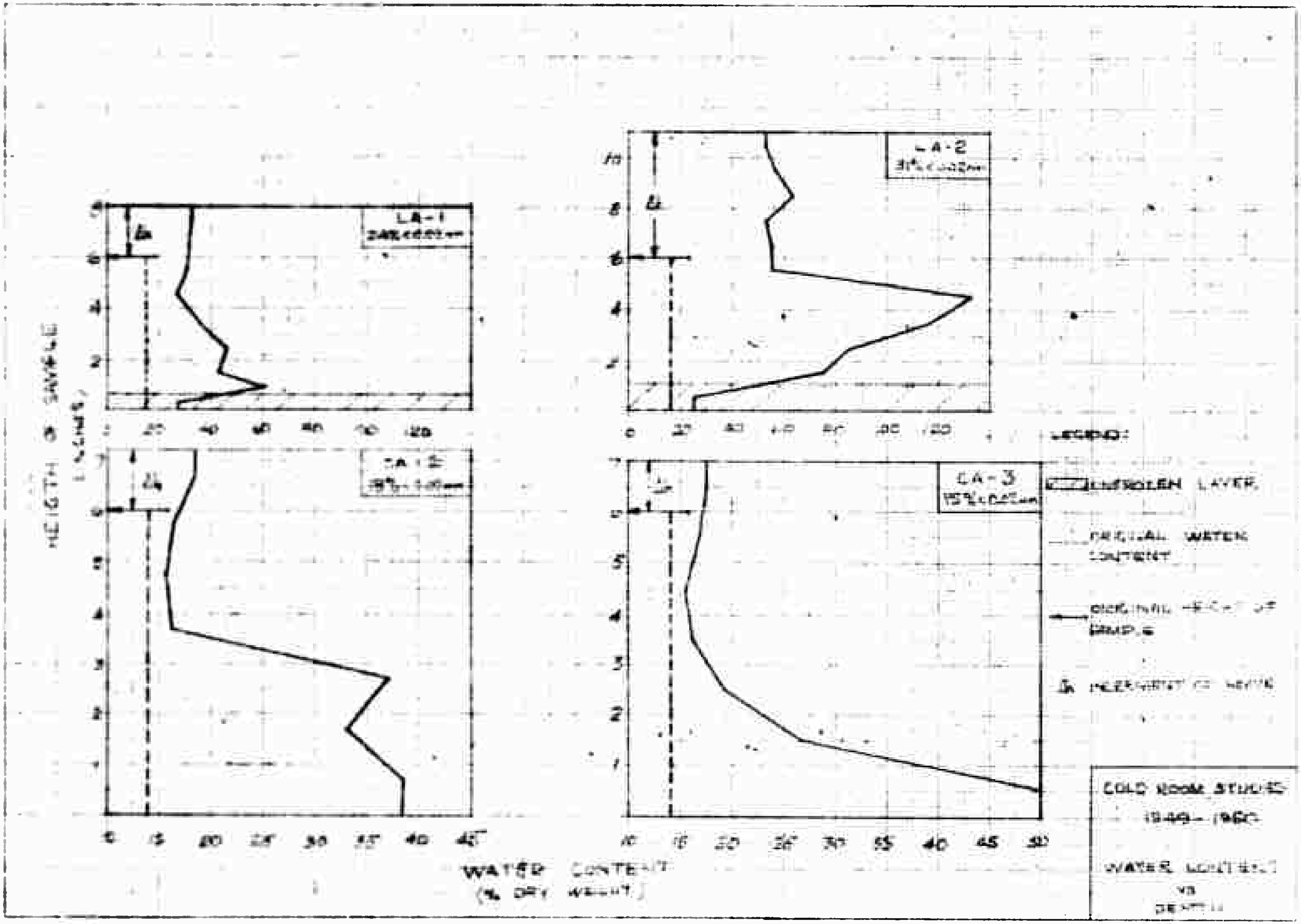

BC-1
84% < 0.02 mm
BC-2
84% < 0.02 mm
BC-5
84% < 0.02 mm
BC-6
84% < 0.02 mm
LENGTH OF SAMPLE (inches)
WATER CONTENT
(% DRY WEIGHT)
LEGEND:
UNFROZEN LAYER
ORIGINAL WATER CONTENT
ORIGINAL HEIGHT OF SAMPLE
INCREMENT OF HEAVE
COLD ROOM STUDIES
1949 - 1950
WATER CONTENT
vs
DEPTH

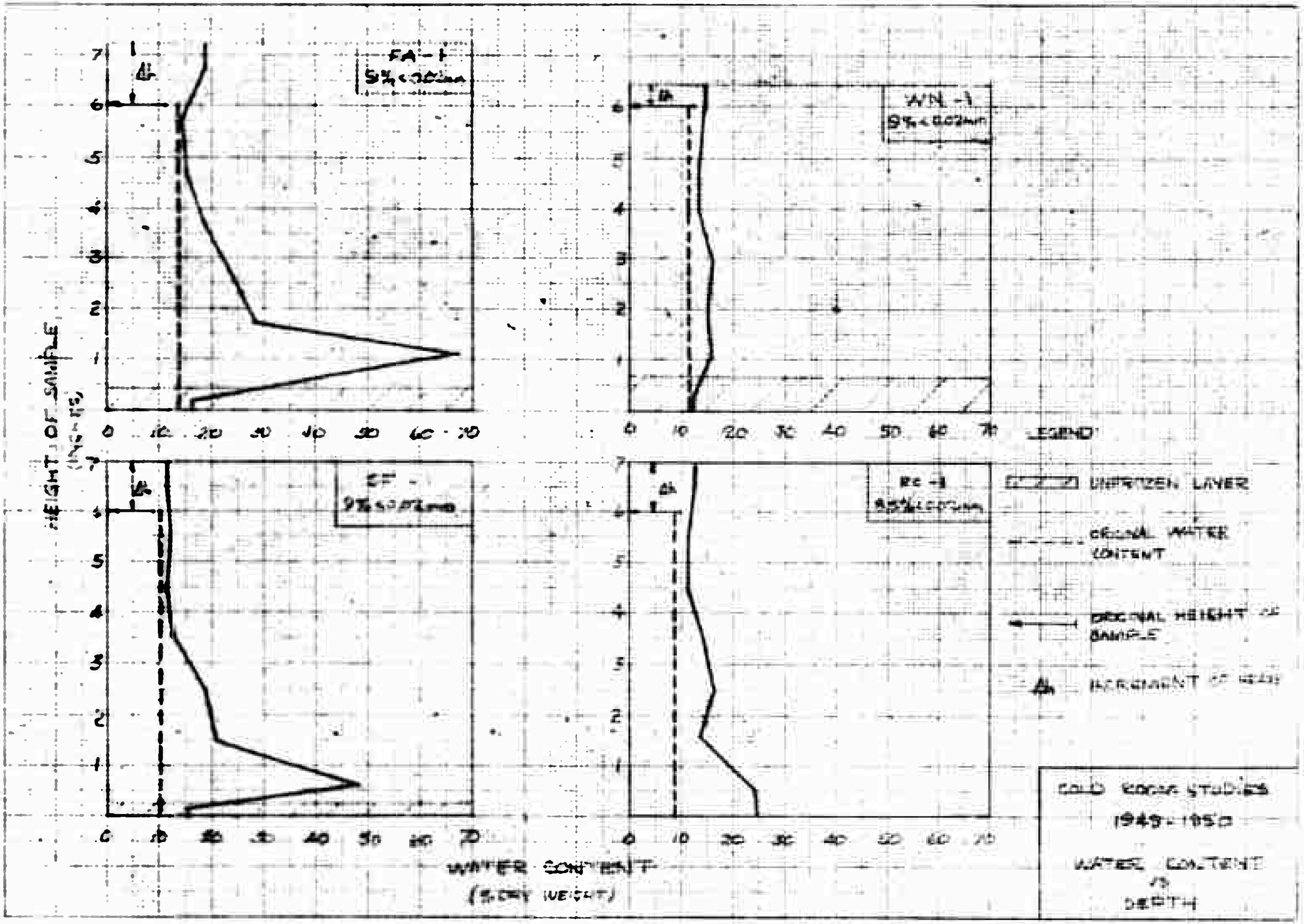


TD-1
TD-2
TD-3
TD-4
LEGEND
UNFROZEN LAYER
ORIGINAL WATER CONTENT
ORIGINAL HEIGHT OF SAMPLE
HEIGHT OF SAMPLE (INCHES)
WATER CONTENT
(% DRY WEIGHT)
COLD ROOM STUDIES
1943 - 1950
WATER CONTENT
vs
DEPTH

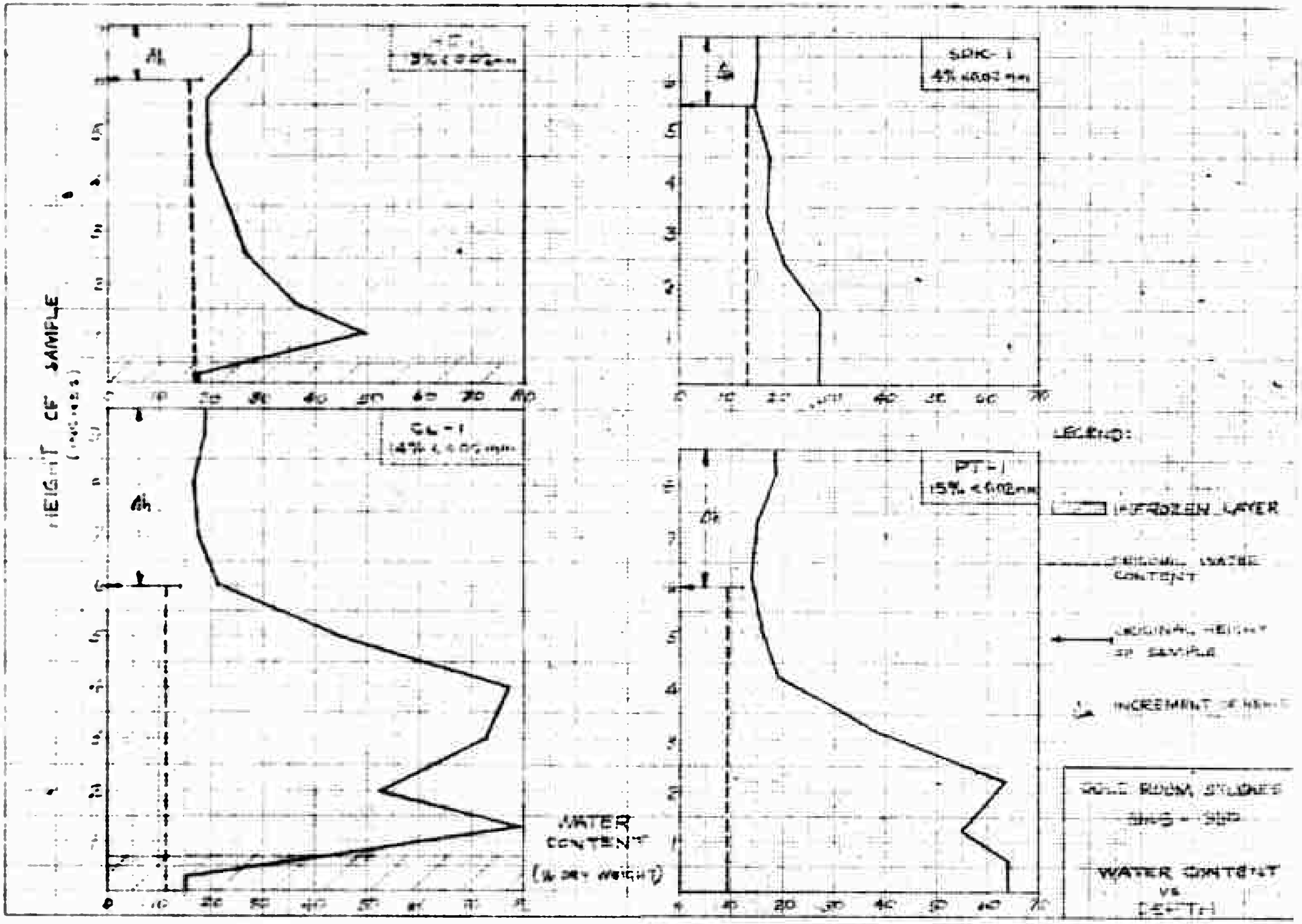


TD-5
TD-6
CA-1
PA-1
HEIGHT OF SAMPLE
(INCHES)
WATER CONTENT
(% DRY WEIGHT)
LEGEND
ORIGINAL WATER CONTENT
ORIGINAL HEIGHT OF SAMPLE
Δh
COLD ROOM STUDIES
WATER CONTENT
vs
DEPTH

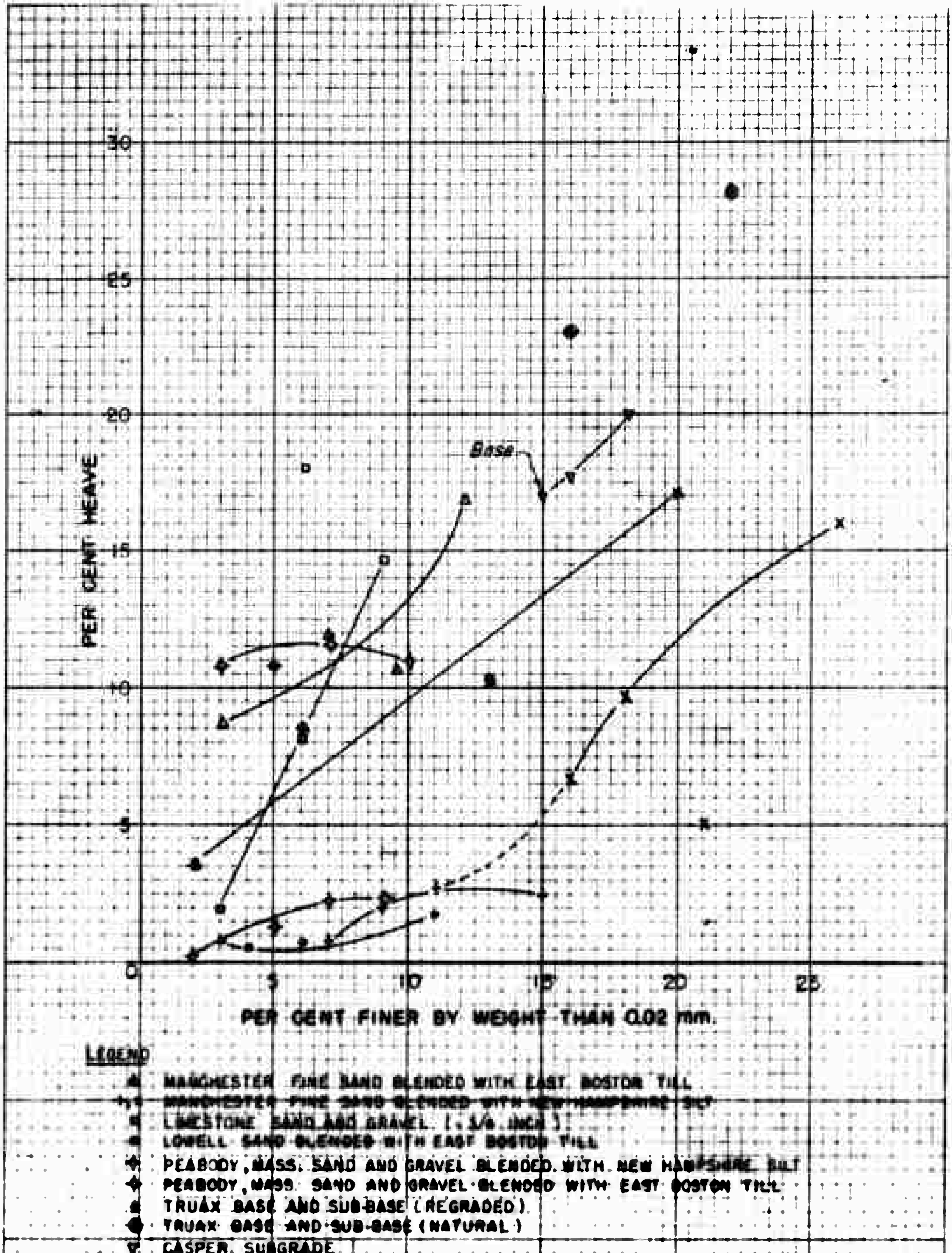

LA-1
LA-2
CA-2
CA-3
LEGEND:
UNFROZEN LAYER
ORIGINAL WATER CONTENT
ORIGINAL HEIGHT OF SAMPLE
HEIGHT OF SAMPLE
WATER CONTENT
(% DRY WEIGHT)
COLD ROOM STUDIES
1949 - 1950
WATER CONTENT
VS
DEPTH



HEIGHT OF SAMPLE (INCHES)
FA-1
WN-1
SF -
WATER CONTENT (% DRY WEIGHT)
LEGEND
UNFROZEN LAYER
ORIGINAL WATER CONTENT
ORIGINAL HEIGHT OF SAMPLE
COLD ROOM STUDIES
1949-1950
WATER CONTENT
vs
DEPTH

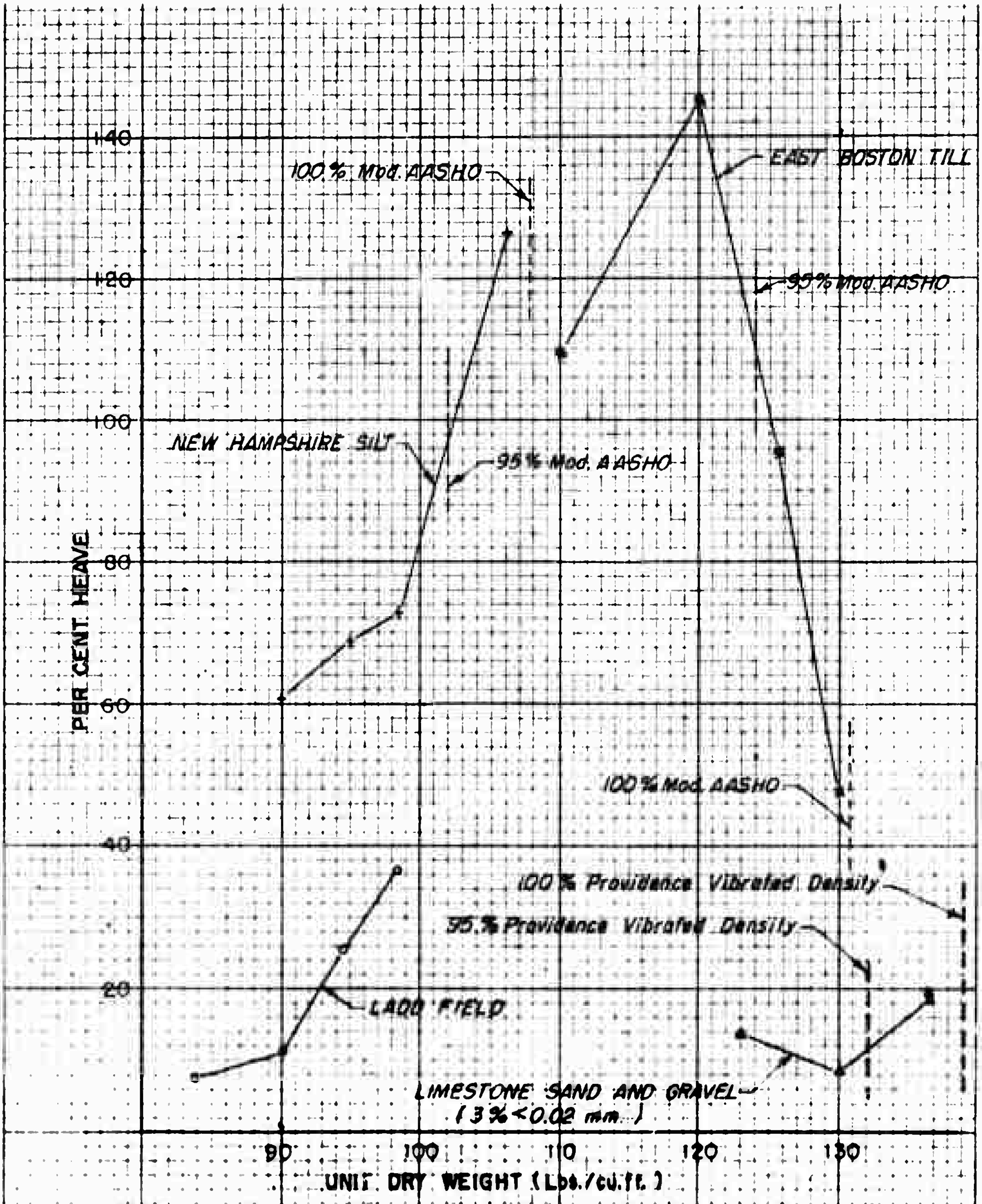


HEIGHT OF SAMPLE
(INCHES)
SPK-1
4% <0.02 mm
CL-1
14% <0.02 mm
PT-1
15% <0.02 mm
WATER CONTENT
(% DRY WEIGHT)
LEGEND:
UNFROZEN LAYER
ORIGINAL WATER CONTENT
ORIGINAL HEIGHT OF SAMPLE
INCREMENT OF HEAVE
COLD ROOM STUDIES
WATER CONTENT
VS
DEPTH



COLD ROOM STUDIES 1949-1950

PER CENT HEAVE VS PER CENT FINER BY WEIGHT THAN 0.02 mm.



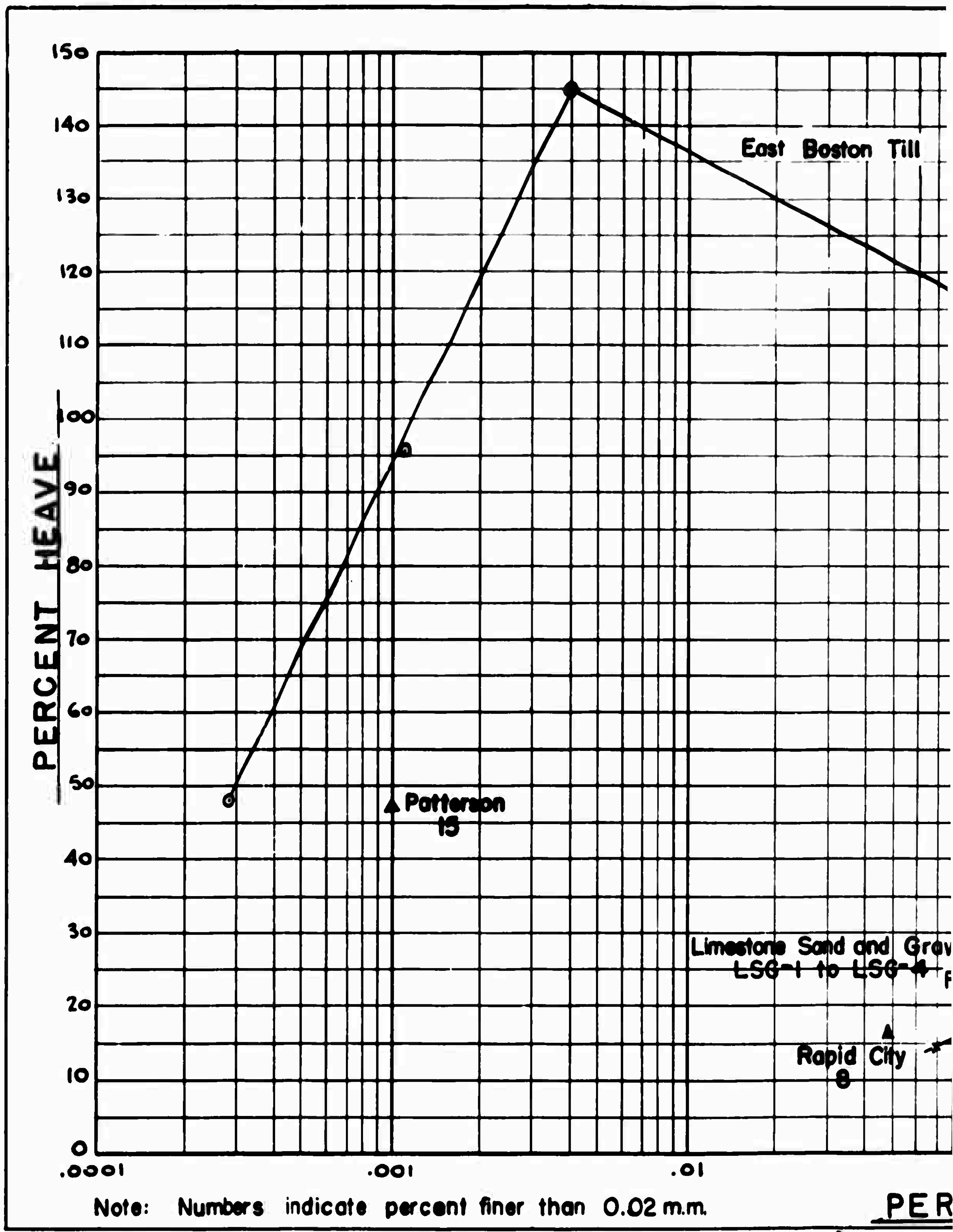
LEGEND

- o SAMPLES LF-1 TO LF-4, INCL.
- + SAMPLES NH-1 TO NH-4, INCL.
- ■ SAMPLES EBT-1 TO EBT-4, INCL.
- △ SAMPLES LSG-5 TO LSG-8, INCL.

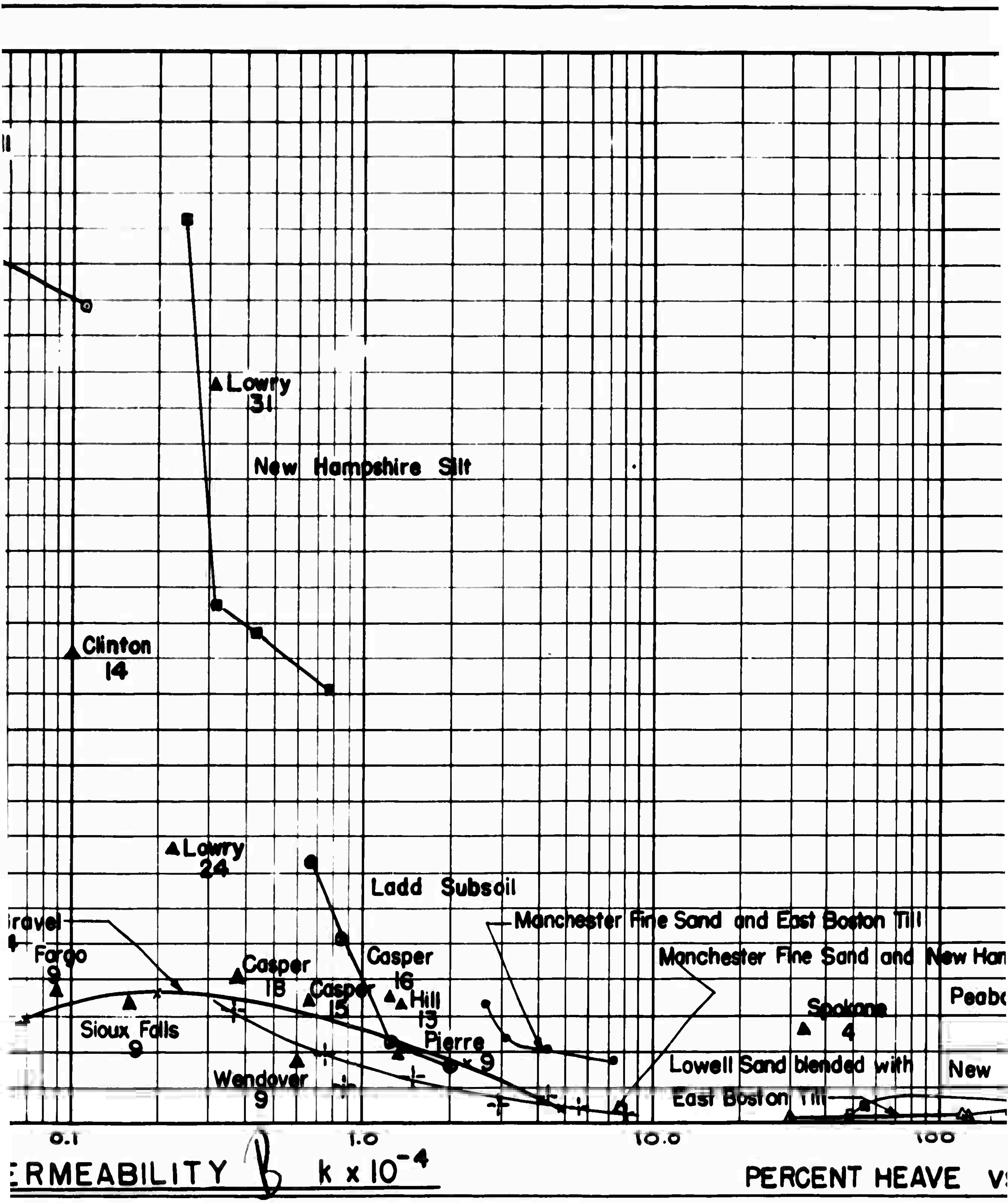
† Test conducted on - 3/4" material

COLD ROOM STUDIES 1949 - 1950

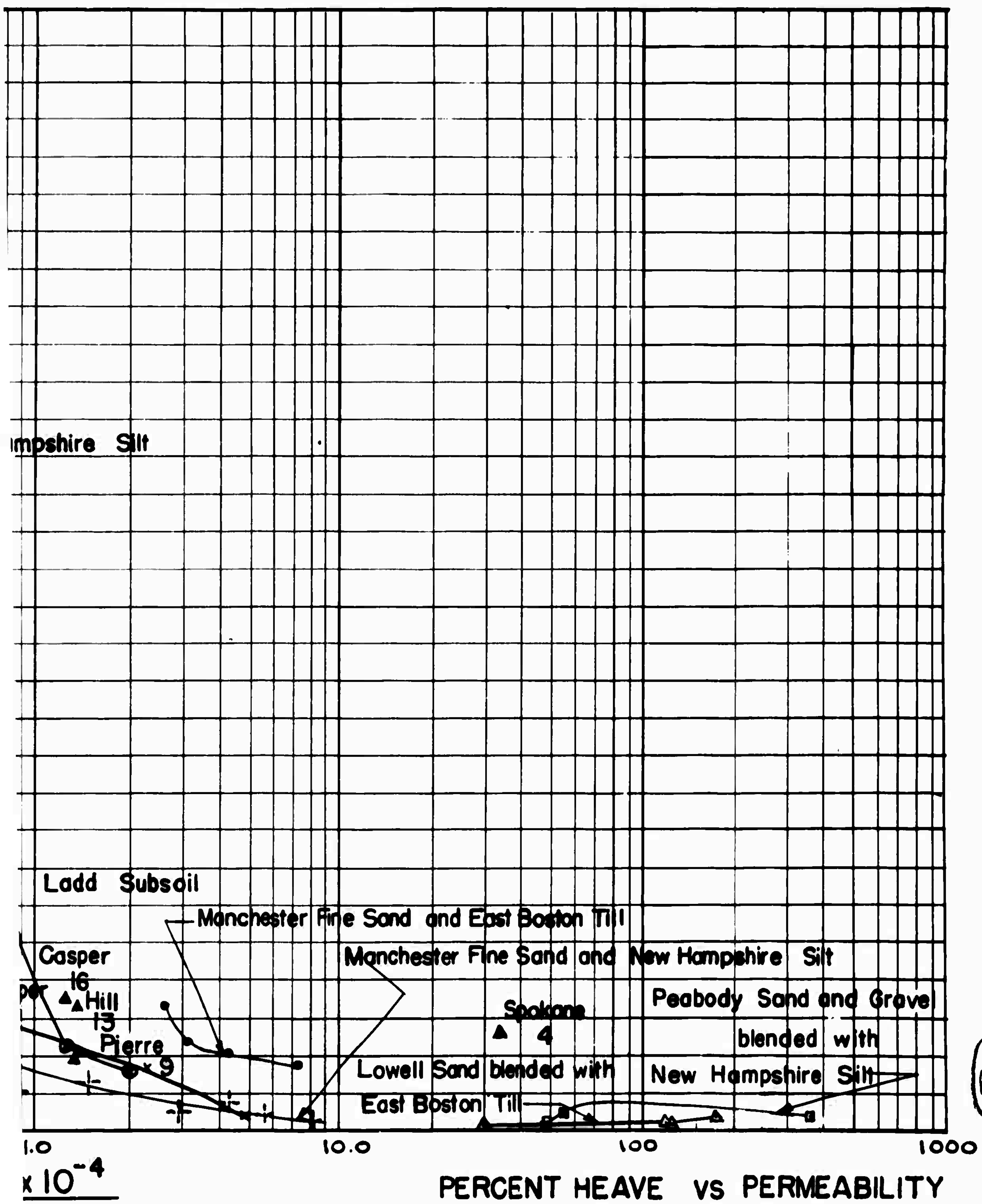
PER CENT HEAVE VS UNIT DRY WEIGHT



PERCENT HEAVE
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
.0001
.001
.01
East Boston Till
Patterson
15
Limestone Sand and Grav
LSG-1 to LSG-4
Rapid City
8
Note: Numbers indicate percent finer than 0.02 m.m.
PER



Lowry
31
New Hampshire Silt
Clinton
14
Lowry
24
Ladd Subsoil
Gravel
Fargo
9
Manchester Fine Sand and East Boston Till
Manchester Fine Sand and New Ham
Casper
18
Casper
16
Casper
15
Hill
13
Sioux Falls
9
Pierre
9
Spokane
4
Peabo
Wendover
9
Lowell Sand blended with
East Boston Till
New
4
0.1
1.0
10.0
100
ERMEABILITY k x 10^-4
PERCENT HEAVE VS



PERCENT HEAVE VS PERMEABILITY

PLATE 72